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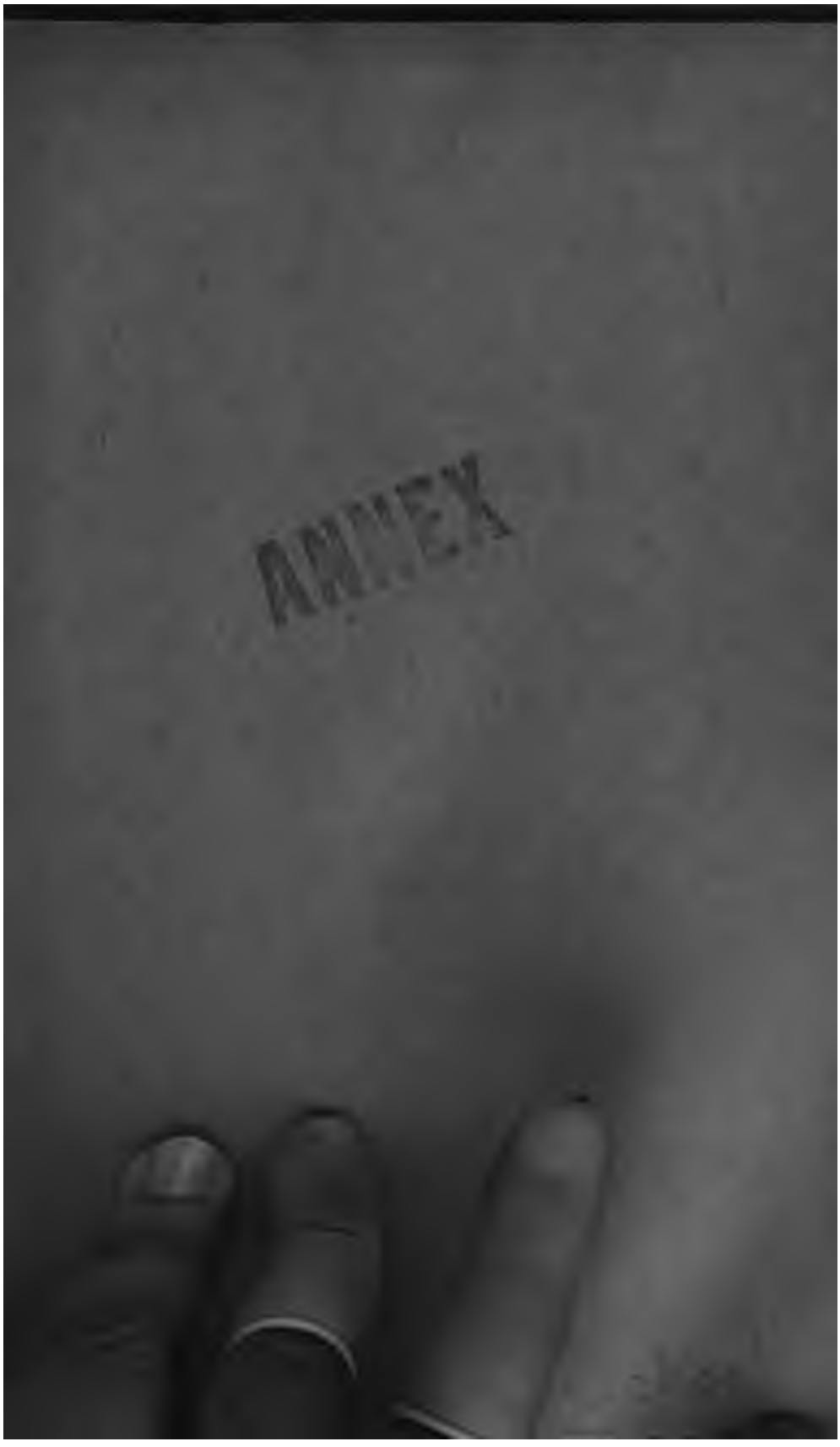
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School Science

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ASSOCIATIONS OF SCIENCE TEACHERS.

BY CHARLES SKEELE PALMER,
Professor of Chemistry, University of Colorado.

Regarding the value of such gatherings as are implied in the subject of this paper, there can be no doubt. It is high time that all teachers of natural science should turn their attention, more seriously than ever, to the growing material available for use in secondary schools and colleges and to better methods of imparting this material to our students, and especially to the secret of kindling their enthusiasm in some one or more of the live, practical helpful disciplines, now offered so abundantly in most good curricula.

And, firstly, get together. A call for a special branch meeting at the same time and place of the regular county or state association, is a feasible plan for a start. Two or three of the more prominent teachers of natural science can well issue the call,—by private letters, by formally printed circulars, or by open advertisement in school journals. But see to it that all teachers interested by reason of their work, their location, or their influence, are included. The Colorado association was suggested by half-a-hundred private letters sent out by a teacher in the State University, on his own responsibility, and the call met with a hearty and unanimous response. The teachers gathered and organized as a branch of the state association, but free to hold meetings at other times and places, as desired, as a quasi-independent society. Be sure to keep close to the main local association, which should represent the unified work of the best in the respective region. Even in the new organization, not disintegration, but union should be the motto. Moreover, there are many related questions which

cannot be settled in the natural science department alone, but which require coöperation. Also be sure and secure at least the tacit encouragement of all principals and superintendents. We shall need all their intelligent sympathy and assistance long before we succeed in attaining the many desirable improvements that will come up from time to time for adoption.

Regarding the machinery of organization, nothing need be said in detail; but keep it all simple; trust each other and do not hamper the possibilities of good work by unnecessary red tape. Let a few responsible, capable and progressive people, as officers, direct the affairs, each in turn for a year. Be wisely generous and foresighted in allowing all subjects, institutions, and sections of country, each a fair representation. Keep down clique; keep up the interest in the main topic—the study and teaching of natural science.

I believe it is a fact of history that the Division of Natural Science Teaching in the National Educational Association (N. E. A.),—as also that which is now the State Association of Natural Science Teachers of New York,—was organized by influences radiating directly from the Colorado organization. In the case of New York, it was this way: The next pending meeting of the N. E. A. was to be held in Buffalo. The secretary of this department in the N. E. A.—who was also an organizer and officer of the Colorado association—wrote to the Buffalo people, asking to be placed in touch with the officers of the state association of New York. The answer came back that there was no such association in existence. The suggestion was made to the Buffalo people that they should use their natural science meeting in the N. E. A., as the occasion and nucleus for the organization of such an association in the state of New York. The suggestion was at once acted upon by the energetic teachers of natural science in Buffalo, and circulars were sent out all over that great state, asking all teachers interested in the project, to gather at Buffalo. At the appointed time, Professor Bessey, of Nebraska, then the president of the Division of Natural Science Teaching of the N. E. A., with others, met the assembled delegates. President Schurman and Professor Gage, of Cornell, were present, and started the ball rolling by their hearty approval; and the latter was

elected president of the newly organized State Association of Natural Science Teachers of New York. Under such auspices and with such management at its head, it naturally assumed at once its proper sphere, and from all that the writer can learn, is still alive and doing a vast piece of work.

For the special program after organization, probably most of the papers will bear on the system and methods followed by the readers of each respective paper. The implied discussion, modification, and adoption of all this will bear obviously valuable fruit. But it may be well to note some of the special subjects for work that the Colorado Association has followed, that being the one with which the writer is best acquainted.

The State University and some other colleges in Colorado had been recommending a preparatory course in natural science, as follows, viz., one year each in physics, chemistry, and biology, and in this order. Of course, there was to be required the implied laboratory method and equipment for each science. The State Association of Natural Science Teachers took up the discussion of the desirable order of science studies, and, on account of the close dependence of physics on mathematics, recommended that physics be deferred till one of the last two years of the preparatory course. This gave that subject some advantage, and led to some specialization therein,—not necessarily undesirable even for the preparatory course, as we recall the magnificent specialization in Latin, Greek, and mathematics which has been not only allowed but demanded for scores of years in all our good high and preparatory schools.

And thus there came to the front as an ideal, the necessity of some sort of specialization in each science,—and the idea is quite likely to remain prominent for some time. Other topics were found in papers—many of them long, exhaustive, and valuable—on the year, the time spent in recitation and laboratory, the books, the methods, etc., for each subject, physics, chemistry, and biology, and sometimes for the related though less fundamental subjects of physical geography, astronomy, and geology. These papers often included reports, collated from hundreds of the larger high and preparatory schools all over the country. In general they all indicated improvement as compared with former times, but seemed

to leave much more to be done in the way of enlarging the scope and improving the discipline.

Perhaps the pleasantest influence connected with these gatherings is the new and warm friendships formed—the writer can speak with great feeling on this point—as also the stimulus that each received to go on and master both the subject matter and also the methods of his particular science.

But organization means life only when it is doing something for somebody else; and these science teachers' associations will find their true significance and value just in proportion as they shall apply themselves to see what the problems are, and then plan a long, patient, dogged course of attack. It is fairly easy to see what ought to be done; it is harder to see what may be done; still harder is it to see just how it must be done. But hardest of all is to see all this, and yet be obliged to wait for years, perchance, till certain changes may come about allowing the bare possibility of new improvements. But this is what many of us must do, and what we are going to have the determination to do, before we will ever relax our constant interest and endeavor.

Among the thoughts which I would suggest for my many colleagues are these:—

Firstly,—is there any one science which is fundamental to and underlying all the others?

Secondly,—if there is such a fundamental science, what is it? and how shall we group the others about this in logical and fruitful coördination?

Can we arrange a course of science which may some day compete, in thoroughness and finish of discipline, with the old reliable Greek, and Latin, and mathematics, and still be fully and truly natural science—really "natural," progressive, fascinating, and productive,—not invidious of the classics and humanities, but recognizing their mutual interdependence and separate value?

I believe that all this can be done, and that it will be greatly promoted by the organization of associations of teachers of natural science.

HIGH SCHOOL ASTRONOMY.

BY GEORGE W. MYERS,
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INTRODUCTORY.

All science teachers, save those of astronomy, agree that beginning students should be given an extended acquaintance with the facts and more obvious uniformities of nature before having much to do with the theories underlying their explanation. Even teachers of astronomy admit that this is the only rational *modus operandi* for other physical sciences than their own. While not disposed to contest the general principle that laboratory, or observational, methods furnish the only sound mode of approaching the study of the truths of nature, most astronomical teachers, and especially high school teachers, see practical difficulties in the way of applying this principle which have hitherto proved prohibitory. As a result, most teachers of astronomy are still clinging to the text-book method of teaching with a devotion worthy a better cause, in the face of the admitted fact that this method has long been relegated to the limbo of the antiquated in all branches of science allied to astronomy.

Instances are known in which the same teacher who planned and executed an admirable preliminary experimental course with his high school class in physics, introduced the same class to the truths of astronomy by the text-book exclusively. Is it not amazing that these things should be so, when we remember that the "wonderful century" just closed, owes the unparalleled advance it has made, at least so far as relates to education, more to the wide-spread introduction of what we have come to know as the scientific method into school work than to all other agencies combined? On the firm basis of this method, discovery and invention have come to be the rule rather than the exception with us. Through it we have learned the true point of vantage for attacking the strongholds of the unknown.

Before the nineteenth century had entered upon its marvelous career astronomers had proved to the world the great fertility of this method for the investigator. It remained to this century

to demonstrate that the method of the investigator is also the method for both teacher and pupil that it is, in short, the method of teaching. How fully and nobly she has performed her task can be judged from the all-pervading prevalence of the scientific spirit of our time.

In the light of these unquestioned facts it is little short of astounding that teachers of elementary astronomy, the oldest, noblest and the most pre-eminently observational of all the sciences, should have responded so feebly to the quickening spirit of the laboratory and observatory. It would seem that after the great astronomical teachers of the pre-nineteenth century had shown the world the true method of teaching, their successors, Esau-like, had renounced their birthright. The few paragraphs which remain to this paper will undertake to discern why this occurred and to suggest a few reasons why modern teachers of the elements of astronomy should return to their inheritance.

It has been but a few decades since astronomy came to be recognized as a proper subject of study for the masses of the people. This was due to a two-fold cause. The wide prevalence among the people of superstitions and of the belief that the subject was suited only to princes, gentlemen of leisure and to the intellectually gifted who were favored with princely patronage, combined to isolate it from the people and from schools. The company the subject had so long kept among astrologers and the nobility even prejudiced the popular mind against it.

The elaborateness displayed by these exalted personages in the erection and equipping of their observatories and the failure of all to recognize the practical utility of the science for work-a-day folk served to content the popular mind that the subject should remain apart from their concerns. The superstitions connected with astrological practices were long cherished by the people and encouraged by quack astronomers, after they ceased to awaken the belief of the educated part of humanity, and these practices fettered the minds of the masses with the indisposition to inquire. Add to this the fact that astronomy was so inextricably interwoven with astrology for centuries as to render the task of ascertaining what was the truth and what error almost hopeless to any but the initiated few, who had no desire to make the distinction.

Again, astronomy, having its beginnings in astrology and in the minds of the people being identified with it, was in their opinion bound to verify the extravagant predictions of the pseudo-science. Failing in this, the real science fell into discredit, so that after the other physical sciences had established the reliability of their conclusions and predictions, they were naturally looked upon as worthier of recognition in educational systems. Those scientists who did succeed in mastering the principles of astronomy and in gaining access to observatory equipment, soon became so engrossed in the beauties and wonders of the sky that they chose to give their thought and time to the pursuit of new truth rather than to popularizing the old. Consequently, they troubled themselves little with popular prejudices against the science.

Finally, a practical acquaintance with astronomy can be attained only by those well versed in the higher mathematics and mechanics. Failing to distinguish between the degree of mathematical attainment needed for making discoveries and what is requisite for understanding what others have done, most persons, appalled by imaginary difficulties, shrink from the supposed task of attempting to acquaint themselves with the elementary truths of astronomy.

However much, or little, reason there may have been in these arguments a hundred years ago, they can have no force with us today. Experience and study have taught us the distinction between the superstitions of astrology and the verifiable acts of science. The only remnants of the pseudo-science which remain with us are a term here and there, and we no longer look up on the tenets of astrology as dogmas of authority. Of late years astronomical advance has been so rapid and so suggestive and the dissemination of knowledge so general that the people recognize both its practical and its intellectual value. In response to the demand of educational thinkers and school managers that the study of astronomy shall be approached as is the study of its kindred sciences by observational work, not a little has been done by Prof. Todd, of Amherst, in his "New Astronomy," and by Miss Byrd in her Laboratory Manual. But so long as the suggestions of these writers remain as printed matter in a text-book they are useless. These suggestions must be put into practical application by astro-

nomical teachers before they can bear fruit. In the later issues of SCHOOL SCIENCE it will be shown that much observational work may be done and much inexpensive apparatus may be devised for experimental work with the stars, and that the old idea that practical astronomical work can be carried on only with the aid of an expensive equipment is wrong.

METROLOGY.*

A FOREWORD.

The Department of Metrology will devote itself in general to metric reform in its broadest sense. Especially will it advocate the adoption and use of the metric system of weights and measures. The schools are wasting many years in teaching a system, or a conglomeration of systems, the parts of which have no connection and are a relic of semi-civilization. Outside of science teaching and scientific research there is no harmony between the notation scale and tables of measures. We add, subtract, multiply and divide in tens; we weigh, measure and compute by 12, 3, 16, 272¼ and many other unrelated numbers.

While the accuracy of instruments of measurement and weight is now greater than it was a century ago, the system and the tables are as clumsy as they were then. We are still content to use a vehicle which a majority of the nations long ago discarded as unfit for use, though the centennial of the new system was passed last year in France.

There is no periodical with a department for metric reform. One struggling organization holds occasional meetings for the promotion of the cause. Possibly a half dozen associations have metric committees. An article now and then in a scientific periodical, or an editorial in some prominent daily, usually favors the metric system. A committee on coinage, weights and measures in

*All communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

Congress is committed to the reform. It reports favorably at each Congress—and there the matter ends.

There is little opposition, but very much apathy. Those who do not know the metric system are legion. Even among scientists who employ it most exclusively, there is much ignorance outside their special field. The chemist who knows milligrams and liters as he knows his own name has but a vague idea of hectares and steres.

The object of this department in SCHOOL SCIENCE may be classed as threefold: 1, Historical; 2, Scientific; 3, Promotive. A series of historical articles will deal with numbers and notation; measures, weights and coinage; chronology, the calendar, circular and other measures, etc. The development and growth of the international system will occupy the foremost place—the history of its adoption, the laws and the progress of legislation in the various countries being a feature, as well as the efforts made to adopt it in the United States, the extent to which it is taught in public schools, its use by manufacturers and individuals, and state laws regarding weights and measures.

In the second or scientific division will be shown the superiority of the metric over the old systems: the great waste of money, time and energy in the use of the latter; and the bearing of the subject on trade and foreign commerce. Books and magazine articles on various branches of metrology will be reviewed, and the columns will be open for discussion of any point.

To promote a healthy, zealous sentiment in favor of metric reform is the third and main object—to awaken a widespread interest in the matter, so that believers in the system all over the country may work unitedly and earnestly for metric reform. A well known educator lately remarked: "I think it a shame that all scientific societies do not unite in a solid movement in favor of the metric system." Chemists and physicists know better than any one else the saving by a general use of the system, for they employ no other, except as they are forced to do so. It is absurd to suppose that any chemist would revert to the old system. But the business man, the trader, the manufacturer, the exporter, in short, the man who does any weighing or measuring would experience a similar advantage from the use of the metric measures.

No case is on record of a nation which has employed this system desiring to go back to its former one.

The use of international weights and measures has gone about as far as it is likely to go in this country without further legislation. In isolated instances manufacturers employ it, but even then they must buy and sell by the English measures, thus making double work of changing from one to the other. To the exporting manufacturer the question is becoming a serious one, for—aside from Great Britain, Russia, Denwark and China—he must sell in metric countries and compete with metric manufacturers. Repeatedly it has been shown by consuls from almost every metric country that estimates given in English measurements are thrown out in favor of those in metric figures. Thus the battle is likely to be transferred from the field of science to that of business.

To the accomplishment of the ends outlined above, the editor of this department asks the coöperation and assistance of all persons interested in the science of metrology—with whom correspondence is solicited—and welcomes any facts bearing upon the subject in its various aspects. SCHOOL SCIENCE is the only organ and exponent in this country of the metric system.

RESEARCH WORK FOR PHYSICS TEACHERS.*

BY PROF. E. L. NICHOLS, CORNELL UNIVERSITY.

The teaching of Physics is in itself a delightful thing, but to be thoroughly enjoyed it should be seasoned with research. Nearly 90 per cent of the scientific work of the world has been done by teachers. But, important as the achievement of the teaching class has been in research, comparatively few of those engaged in the teaching of physics can be counted as belonging to the ranks of the investigator. The principal excuse offered for scientific unproductiveness are lack of time, lack of apparatus, and lack of the

*An abstract of a paper read before the Physics Club of New York, December 8, 1900.

necessary qualifications for the work. The difference between college teachers and teachers in the secondary schools in these respects is much smaller than commonly supposed. Both are overworked, but it is equally possible for both to find time and opportunity for investigation. The real explanation of the unproductiveness of secondary school teachers lies in absence of the habit of investigation, a habit that, like all others, must be acquired by continued practice. Given a well developed habit of experimentation so that a fair knowledge of what has already been done exists, it only remains to select some topic and to study that persistently until definite results have been obtained. While all subjects for investigation are not within the easy range of the teacher in the secondary schools, the list of those available is a large one. It includes among others the study of the influence of absorbed gases and salts or the admixture of liquids, such as alcohol or sulphuric acid, upon the point of maximum density of water; the density and coefficient of expansion of liquids having low freezing points; the verification of the law, already theoretically established, by van der Waals, of the relation of the expansion of liquids to their critical temperatures; the completion of our very imperfect knowledge of specific heats at low temperatures; the determination, in the case of substances not yet experimentally investigated, of the precise value of Poisson's ratio; the study of the temperatures of the flames of burning alcohol and of ether and of carbon disulphide; the systematic investigation of the action of light and of the x-rays on previously exposed plates and the application of the photographic method to various problems in physics, such as photography of absorption spectra in the infra-red.

In this list is mentioned only a few of the innumerable topics available for physics teachers. It is a characteristic of our science that every contribution brings with it a group of further problems to be solved. One cannot read any memoir intelligently without perceiving the possibility of extending the investigation further. Given the desire for research, which is the inevitable result of the habit of experimentation in every one whose mind is fit for scientific pursuits, and the difficulties of time, opportunity, and equipment can be overcome.

The proper stimulus for scientific work is the love of experi-

mentation for its own sake, rather than any desire or expectation of fame; the delight of witnessing the wonderful performance of matter under conditions conceived and imposed by ourselves rather than the hope of achieving some momentous result. At the same time we should not forget that the very simplest phenomenon of nature is worthy of our reverent attention, and that an experiment seemingly unimportant may ultimately be of incstimable value to science.

QUANTITATIVE EXPERIMENTS IN CHEMISTRY FOR HIGH SCHOOLS.

BY LYMAN C. NEWELL, Ph.D.
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Opinions differ widely regarding the nature of the experiments which should constitute a course in chemistry for beginners. There is a growing belief, however, that a course covering the usual time should include some experiments which involve accurate weighing and measuring.

No teacher in chemistry can truthfully deny the fundamental value of exact work. Granting the desirability of acquiring general information, of developing manipulative skill, of interpreting experimental data, and of recording notes in concise English, the problem of effective laboratory work still has another essential factor. Many teachers feel keenly that their pupils often place little confidence in results which are merely observed, that they have a minimum respect for exactness, and that they are contented to do perfunctory work as long as such a performance meets the requirements,—personal or what not. In a word, experiments to be fruitful must contain some feature which will require the pupil to test the accuracy of his own experimental work. This essential is often satisfactorily secured by utilizing judicous questions or by employing confirmatory tests. Such plans, however, demand considerable time, and in some cases actually increase the pupil's mental confusion. The simplest and

most profitable way for the pupil to attain accuracy of head and hand is by the performance of some experiments which rigorously but agreeably demand continuous thought, skill, patience, and judgment. Such experiments are popularly called quantitative.

By quantitative experiments we do not mean "research work," nor the simpler determinations which are included in the customary course in quantitative analysis in colleges. Such work cannot be transferred bodily to a high school. It is just here that some teachers and authors have made a fatal mistake, and they are partly responsible for the negative attitude assumed by some secondary teachers toward exact work. Quantitative experiments intended for beginners should possess those elements which characterize all profitable experiments. For example, they should demand only the average degree of manipulative skill. Skill comes by constant, protracted labor. It is an evolutionary product, and is not possessed by beginners. These very experiments teach skill, and hence we should not assume what we are to teach. Again, quantitative experiments should be simple, but they should yield results which will not shake the pupil's confidence in the possibilities and value of exact work. In other words, the apparatus and methods employed should yield numerical results which are approximately accurate or at least concordant. Indifferent results usually produce indifferent interest. The adolescent mind finds no pleasure in contemplating the "error due to some unknown cause." The beginner has not the spirit of investigation. Furthermore, quantitative experiments must fit the course. They should not require too much individual time and attention, partly because time is not usually available and partly because protracted attention is apt to dull interest and thereby defeat the attainment of one inestimable pedagogical goal, viz., voluntary attention. Nor should such experiments call for complicated, fragile, or expensive apparatus, even though such a sacrifice introduces a small but known, constant error into the final result.

The question of apparatus is doubtless the most serious objection to the introduction of much quantitative work into high schools. An experience of several years indicate, however, that this objection is by no means insurmountable, provided certain principles prevail in procuring apparatus. All the quantitative

work need not be installed at once. Begin with experiments which require apparatus largely in stock, such as large bottles, tubing, stoppers, large scales. Such apparatus accumulates, and if forethought prevails, enough apparatus may be collected in a short time to permit the performance of several experiments. Again, it has proved prudent to buy each year a few pieces of apparatus which are for general use, e. g., accurate balances, weights, graduated tubes, crucibles, hard glass tubing, burettes. This apparatus is not expensive, if the availability is divided by the cost. Judicious selection, likewise, saves money. A thrifty teacher once said: "Count the cost *before* the bill is rendered." A balance or set of weights that will last for years, is worth more than one piece of fragile apparatus for the lecture table, however handsome the latter may be. One balance at ten dollars is not so serviceable as three horn-pan balances, if only ten dollars are available. If the horn-pan balance is encased in a properly constructed box* to protect it from drafts, it will weigh nearly as accurately as the more expensive balance and permit three times the amount of work. Finally, money and time may be saved by performing experiments which utilize a typical apparatus, or one having interchangeable parts. Thus the equivalent of three metals, zinc, magnesium, and aluminum, may be determined by using a apparatus consisting of a small flask, thistle tube, delivery tube, and graduate tube. The same flask may be used in any other experiment demanding one of that approximate capacity, and the graduate tube may be repeatedly used in experiments involving gas measurements, e. g., the determination of the composition of air, hydrochloric acid gas, and ammonia gas. A large bottle (five-pint acid or lithia bottle) may be used advantageously in many different experiments; e. g., in determining the weights of a liter of oxygen or of air, as an aspirator, as a reservoir for water or gas, or as a large generator (for hydrogen, carbon dioxide, and hydrogen sulphide). Considerable expense may also be saved by using apparatus adapted to the same sized rubber stopper. Thus a rubber stopper which is 23 mm. in diameter (smaller end) will usually fit a 500 cc. Florence flask, a 250 cc. Erlenmeyer flask, a

*See Newell's Experimental Chemistry, page 347.

large test tube (8 in. by 1 in.), and a five-pint acid bottle. It is the candid opinion of the writer that expense need not deter a teacher from doing quantitative work in chemistry with his class.

The fundamental aim in utilizing quantitative experiments should be to teach the pupil accuracy, confidence, cleanliness, and a profound regard for exact experimental work. This aim may be accomplished by careful, patient, sympathetic, inspiring supervision of each pupil's work. Such teaching takes time, but no more time than any good teaching. Indeed, as soon as the pupil has learned to weigh, a few preliminary directions or words of caution at a critical point are sufficient, unless the pupil is a born blunderer. The writer makes an especial effort to prevent unfortunate accidents or mistakes due to a large personal equation, which might necessitate the tedious repetition of an experiment. Thus weighings and readings are frequently verified, legitimate sources of error are indicated before the apparatus is taken apart, residues are saved until the final test is calculated. This critical supervision, which is thoroughly legitimate and exceedingly essential with awkward, careless beginners, saves much time and annoyance, and permits thereby the performance of many experiments not necessarily quantitative, which could not otherwise be included in the regular course.

Quantitative experiments should be interpreted from the same standpoint as that adopted in other experiments. The object is to do the experiment as well as possible, not to secure by hook or crook an answer which is theoretically correct, or which pleases the teacher, or which is "better than he got," or which usually agrees with some book. The writer accepts results which are the outcome of reasonably good work, whatever their mathematical value may be. A complete record of each pupil's work is kept, and if improvement is shown, the pupil is ranked accordingly, even though his numerical answers may be somewhat discordant. As a matter of fact, the pupil volunteers to repeat the experiment if the result is erroneous, especially if he knows the source of error and is encouraged to believe that he can avoid this error. Such additional work, however, is usually done outside of the regular laboratory period. Again, the teacher in interpreting quantitative experiments should demand no better results than the apparatus

and method permit. To insist on theoretical results is downright absurdity. As a matter of fact, working conditions (barring the personal element) always determines the value of a final result. An analytical chemist does not strive to get "the theory." He aims to get the most accurate result consistent with working conditions.

For the benefit of those who are skeptical about the results obtained by beginners in quantitative work, the writer cheerfully records here some averages taken from a summary of work done by his classes. It should be said in passing that many teachers who are using the same experiments report results just as uniform and accurate: In determining the percentage of oxygen in potassium chlorate, the average of 23 results was 39.09 per cent; the lowest of these was 38 per cent., the highest was 41.33 per cent, but only three were above 39.04 per cent. In many instances the latter part of this experiment was performed simultaneously with other (simpler) experiments. In finding the ratio in which magnesium and oxygen combine, the average of 27 results was 1.52. In finding the weight of a liter of oxygen, the average of 24 results was 1.449 grams; of these results, the two lowest were 1.40 and 1.44, the two highest were 1.46 and 1.49. In a similar class of more patient pupils, the average of 8 results was 1.43. In finding the equivalent of zinc, the average of 19 results was 32.43, of 25 results was 32.30. The result in the latter series varied from 31.5 to 33.0. The average of 23 determinations of the water of crystallization in barium chloride was 14.88 per cent; half of these results were between 14.66 and 15.00, and none was above 15.00. The average of 21 (another set) was 14.71 per cent; only three of these were above 15.00 and 11 were exactly 15.00. The experiment followed the three above mentioned and the results demonstrated undeniably the acquisition of skill, patience, and care. This experiment, as in the case of the determination of oxygen in potassium chlorate, once started, was allowed to "run itself" while the pupil performed other experiments. The average of 22 determinations of the oxygen in air was 20.64 per cent; and of 39 determinations was 20.97 per cent. This experiment involves considerable care, but is exceptionally instructive.

The results were uniform, though often somewhat low owing to the difficulty of removing the last traces of oxygen.

The manner of conducting laboratory work of a class performing quantitative experiments varies with the conditions. If the divisions are small, the experiments can be done by each pupil, but if the divisions contain fifteen or more, it may be necessary for two pupils to work together. Some experiments are admirably adapted to the latter procedure. In such cases, it is advisable to require each pupil to calculate the results independently. Considerable time may be saved by allowing the calculation to be made outside of the laboratory, especially if the operation has become so familiar that accuracy is the only essential. Many teachers do not permit pupils to read the barometer, and the writer has a growing belief that such a prohibition is prudent. A reading taken by the teacher and posted in plain sight will be sufficiently accurate for the laboratory period. Considerable annoyance and delay may be avoided, if general conditions are carefully and regularly scrutinized by the teacher. If gases are to be measured over water, the water must be kept standing in the laboratory long enough to allow it to assume the temperature of the laboratory, and if its temperature is to be determined, as is often the case, the same thermometer should be used for successive determinations. A few trials will reveal the best location for work with gases, e. g., out of the direct sunlight or away from hot air drafts. Beginners are apt to estimate weights and readings. Such a fault needs immediate and unequivocal discouragement. Pupils soon detect which way to estimate and some have little compunction against manipulating data, especially if the experiment has an excessively large disciplinary element. Beginners should be taught to accept the truth, whether such acceptance is agreeable or not. It is advisable for the teacher to make enough preliminary trials of an experiment to determine the limits of error. Such a precaution will reveal what results to accept. With some classes, especially mature pupils who look forward to advanced work in science, these preliminary trials provide a fruitful opportunity for investigation. Let them discover the errors in the method or the defects in the apparatus. Many a pupil discovers himself in such work—a most profitable discovery.

Quantitative experiments in chemistry furnish an attractive basis for the discussion of chemical theory. It brings the beginner face to face with the harmony and unity of nature. He sees the truth and realizes that the outer truth is recognized only by a consciousness of inward truth, for "that only which is within can we see without."

A TEACHER'S INDEX OF CURRENT PHYSICAL LITERATURE.

BY GEORGE FLOWERS STRADLING.
Instructor in Physics, North East Manual Training School, Philadelphia.

For three years the writer has kept an index of those parts of the literature of physics which he has desired to retain within mental reach. To him the result has grown to be of so much importance and help that he takes this opportunity of describing his method to his colleagues.

The outfit consists of a bookkeeping journal of 600 pages, of a lettered index, and of a letter-file, the respective prices of which are about 60, 25 and 30 cents.

Under the letter A of the index, the following is a part of what is found:

24.—Alloys.
11.—Action at a distance.
53.—Atmospheric electricity 460.
218.—Atmospheric pressure.

The number 24 before the word "Alloys" refers to the page in the journal which has this word as heading. On this page are more than a dozen references. The first is Roberts-Austen: On Alloys. Important. N. 2, 18, 377, '97. Thus I learn that on page 377 of the copy of "Nature" for Feb. 18, 1897, is a good article by the eminent authority whose name is given. Following the above are references to

Application of x-rays to study of Alloys.
Freezing Point Curves of Alloys of Zinc.

Micro-structure of Alloys.

Heat of Formation of Alloys.

The periodicals cited are "Nature," "Philosophical Magazine," "Electrical World and Engineer," "Chemical News" and "Proceedings of the Royal Society."

The index contains altogether more than 160 different scientific headings, almost exclusively physical in character. This list grows quite rapidly. The work done by J. J. Thomson and the Cambridge physicists on the conduction of electricity through gases by ions led recently to a new title, Ions.

When, in looking through a periodical, I see an article or paragraph that seems to have permanent value, I enter it on the front page of the journal, and thus by the expenditure of no great amount of time, I come to have a list of the newest articles treating of the subjects in which I am chiefly interested. When a lecture is to be prepared, I have ready at hand a list of references which will put me in possession of what is most recent on the subject. When I want to have my students learn something of the value of periodical electrical literature, I turn to the index and find both subjects and material for essays. In addition to these objective advantages, there is the subjective one that I feel a satisfaction in the confidence that when I read a good thing, it is not allowed to drop from sight, but is written down where it can be readily found.

The letter-file is used to hold clippings. These are indexed just as articles in magazines are, the location reference giving the letters of the file where they are kept.

In these days when the card catalog is pre-eminent, no doubt any one who reads what I have written, if he does me the honor to reflect at all, will wonder why I did not adopt a card catalog. The reason is that I found my plan to be far the cheaper. Besides a page has the advantage of *Uebersichtlichkeit* in comparison with a row of cards, and the index has occasionally to be carried to school.

The forming of the index has been a stimulus to me. I now index about twenty-five or thirty of the chief physical journals, and feel a certain modest pride that nothing of great value that is published escapes being set down in the index.

THE TEACHING OF PHYSICAL GEOGRAPHY.

BY WM. H. SNYDER.
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What is physical geography? The best definition is, the study of the relation of the earth to man. What does this mean? It is not a study of the structure, compositions, motions, activities or surface conditions to simply find out why they are what they are, but it is the study of their action and development upon the life and industries of man. We have to do with molar, not molecular nor atomic activities. Nature's jack plane and the plow are the things we have to consider, not the microscope nor the vernier. We want to examine, not the small forces that simply helped out, but the great forces that have made the mighty changes on the earth. The rocks decay, we don't care why. The mountains and plateaus rise, we don't know why. All we want to know is what effect these changes have upon man's dependence upon the earth and conquest of it. That man is not dependent upon the earth for his condition and subsistence none of us would for a moment claim. Artificial as our lives may have become, yet in their finality they hark back for everything to mother earth, and it is her moods that sooner or later determine what we are to do and be. Our conquest of the earth, like our conquest of everything else, will depend upon how well we understand the situation we are called upon to meet. It is hardly profitable for us to waste our time digging artesian wells on the rocky slopes of old granite mountains or to dig for gold in the stratified beds of the Mississippi valley. We would hardly expect to find a large city at Crawford Notch or to learn of a manufacturing town at the mouth of Penobscot. "Tear our hair" all we have a mind to, we generally do just about as old mother earth has arranged for us to do. As it is interesting as well as profitable for a man to know what he is allowed to do and how he is allowed to do it, so is it interesting and profitable for us to know something about the earth and its "thou shalts."

Let us, then, remember that in teaching physical geography not man alone nor the earth alone are the important factors, but

that it is man and earth with which we have to deal. A teacher cannot get this humanistic aspect too clearly into his mind. Boys and girls are not interested in abstractions. They may do for the doctrinairs, but for the full blooded boy who intends to get out into the world and make money and reputation by dealing with men and materials they are about as attractive and nourishing as sawdust pancakes. He wants to know what effect the thing you are trying to teach him has upon the present or the past races of men. If physical geography will explain history or present human conditions to him, he will study it, be interested in it and try to really think about it. If not, he will read it, try to recite it, and readily forget it. This does not mean that all the abstractions and difficulties must be taken out of the science. It means simply this: See that all the teaching is tied up to something that a pupil really believes has somewhat to do with the things in which he is interested. If the boy lives on a rocky New England farm, cause him to realize clearly why his father does not raise great fields of wheat or ride a sulky plow or use a four-horse reaper and binder in getting in his grain. If he lives in a manufacturing town, let him try to decide why there is manufacturing in the town and why they manufacture what they do. I will admit it is rather hard in the present days af advanced psychology and pedagogy to tell exactly what we poor school teachers are placed on this earth for. However, until the contrary is more conclusively proved than at present, let us take it for granted that one of our functions at least should be to knock a little thinking, either into or out of a boy's head. To be sure, the subject of physical geography has to deal mostly with generalities and things in the large, but boys and girls rather like this. They have not yet come to the point where they want the government to coin five-mill pieces so that they can split a cent. Life and the world is big to them. This isn't a bad thing, either. We all of us become withered up soon enough, become pessimistic and look at the small side of life. Will not the study of the grand products formed by the mighty tools of the Almighty hand stimulate the mind to noble thoughts and aspirations more strongly even than the study of man's greatest deeds and thoughts? And after all, what is education but an attempt at inspiration? If its aim is simply material-

istic, then the boy should be taught to read, to write, to figure, and then be placed in the shop. We none of us believe this, however. We want to fill the mind with the best, the most noble and elevating incentives, that he may live for something besides the attaining of mere subsistence and of self-gratification. Let us, then, try to show him something of the grandness of Nature, and through Nature of Nature's God. If physical geography can aid in this attempt, by all means let it be taught him and taught him aright.

If we grant, then, that physical geography is a worthy subject for our study, how ought it to be taught? A subject may be ever so worthy and ever so valuable, and yet so taught that it will be dull and almost valueless. Now, almost everybody thinks that he knows enough to teach physical geography. I am told that the embryo teachers in sending in a statement of their qualifications to the agencies almost invariably assert that they are able to teach this subject. Many of them, of course, never studied it a day or ever did more than to look through the pages of some antiquated textbook, and perhaps try to fasten in their minds a few statements which, as Humboldt used to say, "are very interesting, if true." Whether they are true or not, these teachers have not the slightest conception, for all their knowledge rests upon the authority of the particular book they happen to have in hand. The work of such teachers we cannot expect to be instructive, inspiring or reliable. A teacher never taught anything successfully that he had not spent some time and energy preparing himself to teach. He would not think of attempting to teach mathematics or Latin or Greek unless he had studied them and studied them for a considerable time. And yet these subjects are narrow in their elementary scope, and a person may be a pretty successful drill master in the elements without having very much knowledge of the subject. Physical geography, however, even in its elementary aspects, must be broad. It must embrace much general knowledge and the power to draw correct inferences from observed and recorded observations. This ability cannot be obtained from simply reading a textbook. It must come from proper instruction and proper thinking. The mind that is to broaden the pupil's mind must itself be broad. Interest and

inspiration can come only from one who has a grasp of the subject and can add to the mere statements of the textbook some personal experience or acquirement. These statements are applicable to all subjects, but they peculiarly apply to this subject, where the eye and the observing power must be called into play as well as the printed page and the memory.

Now the fact of the case is, physical geography is one of the hardest subjects in our high school course to teach, because it is not simply a book or laboratory subject. It must combine the book, the laboratory and the field. It must call in play the retentive, the productive and the observative faculties. Some subjects can be learned from books, some from books and laboratory, some from books and field, but physical geography needs book, laboratory and field. Embracing all three of these methods, it has a certain value of which no other subject can boast. The fact that it corrolates these three methods and brings each of them to bear upon its continuous development peculiarly intensifies its value. The trouble is that the physical geography is rarely worked for what it is worth in the educational system, because of the newness of development along this line. We have not yet assimilated the subject into our curricula. In many schools it is rather a fill-in than a filling subject. It occupies a place where there can't anything else be easily put. It is taught by the teacher who really can't very well do anything else, and is taken by the pupils who really are not exactly suited for anything, and is taught with, well, any book that is easy. Under these conditions, no wonder that it is considered dull and uninteresting.

Let us, then, concede that the *sine qua non* in the teaching of physical geography is a knowledge of the subject on the part of the teacher, that this subject like others must be one which has been thoroughly studied. Let the teacher of physical geography feel that this subject deserves his careful preparation and energy while instructing as well as any other. Where there is a will there is a way. When it is really for the advantage of us teachers to know a subject, we go to work and find out where and how to learn it. A few years ago any one was supposed to be able to teach physics, but the grade of work demanded has risen in the last few years, and now every one that teaches physics makes

some special preparation for the work. When a man is engaged to teach the subject, inquiries are made as to whether he is qualified. Men find it necessary to their procuring positions that they give time and work to this subject and they do so. When it becomes apparent that the teacher of physical geography must needs be prepared for the work before taking it up, then this preparation will be made. There is no reason why this should not be as well taught as any other subject. It can be studied as readily and acquired as easily. Several places in this country where the subject is well taught may now be found. Then, too, there are the summer schools, where good courses are given every year. These will give a good start in the preparation, and here, as elsewhere, a right start is one of the most important things. It must be followed, however, by continual reading, study and, if possible, travel, to keep in touch with the developments. Physical geography is not remaining stationary; new things are being found out and new methods of investigation are constantly being devised. The field is open; there is no best method; every energetic teacher is trying to see if he cannot discover some way that is especially adapted to his needs. When the broad view of the field is once gained there cannot be too much of this independent effort. The best way to teach the subject will be discovered by a lot of patient workers working together and honestly trying to find out how to accomplish the best results. And then, too, there can never be any absolutely best method, thank goodness. The teacher in New Hampshire ought not to teach the same as one on the Alabama coastal plain. The school work in physical geography must have a local flavor. It needs to proceed from the seen to the unseen. The local surroundings must furnish the base level for reckoning. You cannot build an air castle of geographical forms; there must be a foundation for the structure laid at home. Here lies a source of great advantage, but also of great difficulty. However, when teachers can get the proper training the difficulties will be done away with, but the advantages will remain.

There are few places which do not show in miniature many of the great features of the earth's surface. The plain, the hill, the valley and the brook are typical of the great plains, the moun-

tains, the great valleys and the great rivers. Their influence upon population, too, is in a small way the same as that of these larger features. The plains in New England are generally sandy and are not such good farming lands as those of the great plains of certain parts of the earth, but, like them, the land is easily cultivated, the roads run in straight lines from one point to another, the valleys cut deeply into the soft soil, the wells must be dug deep and manufacturing is not found.

(To be continued.)

SOME WAYS OF DEPRIVING GERMINATING SEEDS OF AIR.

BY LOUIS MURBACH.
Instructor in Biology, Central High School, Detroit, Mich.

In schools where an air-pump is not always at hand for removing air from soaked seeds, to lead pupils to see the need of oxygen in germination, the vacuum of the physicist's water-hammer may be made to serve the same purpose. With a little practice, some glass tubing and an alcohol lamp (Bunsen burner is better), ten minutes will suffice to put the seeds in the vacuum.

Close, by softening in the flame, the end of a glass tube ten inches long by one-fourth inch in diameter, and drop small soaked seeds down into the closed end. Push down a little coil of wire or bristles to hold the seeds in this end when the tube is inverted. After filling the tube one-third full of boiled water, draw out the open end. Heat the tube in the flame until it is soft enough to bend easily, and break the drawn-out part where it is one-sixteenth or one-thirty-second of an inch in diameter. Now hold the tube carefully in the flame just below the water level until the water boils gently. The steam formed drives the air out of the tube, while the seeds are too far below the flame to be injured. As quickly as possible seal the fine tip by holding in the hottest part of the flame and allow the tube to cool before turning it over. The vacuum may be known by the "hammering" of the water when the tube is shaken endwise. If successful, the seeds will be in a

moist vacuum when the tube is turned over. If not successful, the point of the tube may be broken off and the process repeated..

After three or four days, other seeds of the same lot having germinated in the air, the seeds in the tube may be removed by breaking it, and if kept in a moist chamber, will germinate.

Where mercury and a glass tube of barometer length (about thirty-three inches) can be had, a more satisfactory vacuum may be made. Into the closed end, as in the first case, drop or push some small soaked seeds (morning glory, alfalfa) and then a little coil of wire to keep them in this end. Fill the tube with mercury, tapping and turning the tube from time to time to remove air. Invert the tube in a dish of mercury and leave until some seeds of the same lot, kept in a moist chamber near by, have germinated. After pupils have written up the experiment, remove the seeds from the vacuum and they will germinate rapidly, showing that they were not killed.

A very simple method that can be used with young students, but less certain unless very carefully done, is to displace the air with carbon dioxide from the lungs. After soaked seeds have been placed in the bottom of a Mason fruit jar (pint) the air is replaced by breathing through a glass tube for several minutes, then cautiously withdrawing the tube until the cover can be slipped on in the same careful way, and the jar sealed air tight.

In all these experiments the seeds should not be soaked too long.

A NEGLECTED FEATURE IN FERN STUDY.

BY J. A. FOBERG.
English High School, Chicago.

The careless visitor to the ferneries of our parks does not see the tiny, green, heart-shaped growths on the rocks and soil near the ferns, and is probably surprised when they are pointed out to him and spoken of as fern-plants. These "fern-prothallia" of the botanist are developed from microscopic, non-sexual spores borne

upon the under surfaces of fern-fronds; and upon them are developed the sexual organs and spores from which grow the ferns of ordinary speech. To study these prothallia, they must be specially prepared, and the microscope must be used.

The plants can be collected in any fern-house, preferably from the rocks, since then fewer particles of soil are entangled among the root structures. A pair of curved forceps, or an ordinary knife-blade, may be employed to remove them from the rock, care being taken to prevent bruising. The prothallia may be at once dropped into 2 per cent formalin, which is a killing and preserving fluid, and may be left in this until wanted. A fairly satisfactory method of then preparing the prothallia for study is this: Remove the prothallia from the formalin, and wash thoroughly in clear water; place for three or four hours in a mixture of 3 parts water, 1 part glycerine, and then for the same length of time in a mixture of half water, half glycerine. Put now into a liquid 1 part water, 3 parts glycerine, and let stand until the water evaporates, leaving the prothallia in concentrated glycerine.

Permanent mounts may now be made by making a ring of balsam in the middle of each slide, placing in the center of each ring a drop of glycerine with a prothallium, lower side up, and covering with a cover-glass supported by three or four fragments of thin glass. One or two experiments will be necessary to determine the right amount of balsam and glycerine to use, so as to avoid air-bubbles.

For the benefit of those unfamiliar with this small but interesting stage in the life history of the fern, a few words of description may be added. The prothallus varies somewhat in size, according to the species of fern producing it, but it is never large and always requires the aid of a compound microscope to make out its structure. It may commonly be seen by the unaided eye as a very small heart-shaped thallus. On examination with the microscope, viewing the under surface, the structure is largely cellular, with numbers of hair-like rhizoids extending from the central, thickened basal portion. Mixed up with the rhizoids will be found the remains of sporangia, and here and there very small rounded cells, usually with a darker central marking, the *antheridia.*

Near the sinus or notch of the prothallus a number of small, oval or rounded dark structures may be seen, often appearing to be made up of minute cells. These are the *archegonia.* By the fusion of the contents of antheridium and archegonium, a sexual spore or "egg" results, which on germination produces the fern plant, as it is commonly known.

A CONVENIENT METHOD OF DETERMINING THE DENSITY OF AIR.

BY A. W. AUGUR.
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A rapid and reasonably exact method of determining the density of air both for the laboratory and lecture room is of considerable interest and importance to every teacher of elementary science. The method here described is believed to meet the requirements of simplicity, speed, and accuracy better than most of those commonly employed.

The apparatus required consists of a copper or brass globe provided with a stopcock, such as usually forms one of the accessories of an air pump; a balance weighing to centigrams; a bicycle pump; a two-gallon bottle provided with a four-hole rubber stopper, and graduates or graduated flasks for measuring the volume of water. The globe is weighed filled with air at atmospheric pressure, the stopcock being left open. With the bicycle pump as much air is forced into the globe as is thought safe. If the globe has soldered joints, 1.5 to 2 grams of air for each liter of capacity will usually be safe; but if spun without joints, a much larger amount of air could be forced in. The globe is again weighed and the weight of the air introduced noted.

The large bottle is filled about two-thirds full of water at the temperature of the room, and a layer of heavy lubricating oil poured on top to check the formation of water vapor when the relatively dry air from the globe is admitted. Kerosene might be

used instead of the water and heavy oil with good results, but was not employed by the author. A bent glass tube passing through the stopper nearly to the bottom of the bottle and provided on the outside with a rubber tube and pinch cock acts as a siphon for drawing off the water. A second glass tube with a rubber connection for attaching to the stopcock of the globe passes through the stopper and provides for the admission of the air.

A U-shaped open manometer tube 25 centimeters high, and containing about ten centimeters of water with the outer end provided with a rubber tube and pinch cock, passes through the third hole in the stopper. A thermometer is inserted in the fourth hole, the stopper is wired in, and all the connections made tight with soft wax or paraffine.

The globe is attached to the inlet tube and enough water allowed to run from the siphon to make the pressure, as indicated by the manometer, the same inside the bottle as outside. The open end of the manometer is then closed by means of the pinch cock and the air from the globe admitted rather slowly, taking perhaps two minutes to complete the operation. In the determinations made by the author the water is drawn from the bottle directly into liter flasks, the fraction of a liter being measured in a 500 cc. graduate. When apparently enough water has been drawn out the pinch cock is removed from the open end of the manometer and water allowed to run in or out as may be needed to make the pressure inside and out the same. As the air in the globe is cooled by its expansion, two or three minutes must be allowed for it to again reach the temperature of the room. The thermometer and barometer readings are then noted.

The following are fair samples of the results obtained after reduction to 0 degrees and 760 mm.:

Density.	Per Cent Error.
0.001297	+0.31
0.001279	—1.08
0.001289	—0.31
0.001293	0.00
0.001291	—0.15
0.001302	+0.70

The largest error in 15 successive determinations was 1.3 per cent, the average error being 0.54 per cent. The weight of the air taken was from 3 to 4 grams, and the weighings were accurate to centigrams only. The time required for a determination never exceeded 20 minutes, and was usually about 15.

Aside from instrumental errors, the chief sources of error in this method are due to the cooling of the air on expansion, and the formation of water vapor when the relatively dry air from the globe has displaced the water in the bottle. If the bottle is not more than two-thirds full of water and the air is admitted slowly, the error from cooling, which tends to make the result too large, will be small. If we wait till the air has fully returned to the temperature of the room so much water vapor is likely to form that the result is certain to be too small. Until the layer of oil was used this was uniformly the case. The most satisfactory results were obtained when from two to three minutes were taken for the admission of the air and the drawing off of the water.

EXPERIMENTS ON THE REMOVAL OF OXYGEN FROM THE AIR.*

BY O. OHMANN.
Berlin.

Quite a number of methods have been devised to separate the oxygen from a measured volume of air, and thus to show the ratio of the volumes of oxygen and nitrogen. Phosphorus and pyrogallic acid in alkaline solution gives perhaps the most accurate results; copper is good, but requires rather complicated apparatus, while, of course, the use of combustibles, such as alcohol or a candle, is barred, because carbon dioxide is formed, which cannot be readily separated from the nitrogen.

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*Translated for "School Science" from *Zeitschr. f. phys. und chem. Unterricht* XIII. 333.

In what follows will be shown how the oxygen may be removed by burning hydrogen, and that a very satisfactory determination of the ratio of the volumes of oxygen and nitrogen can by this means be made. The experiment is not offered as a substitute for other methods of making this determination, but it is thought that it may well be incorporated in the study of water or the general phenomena of combustion.

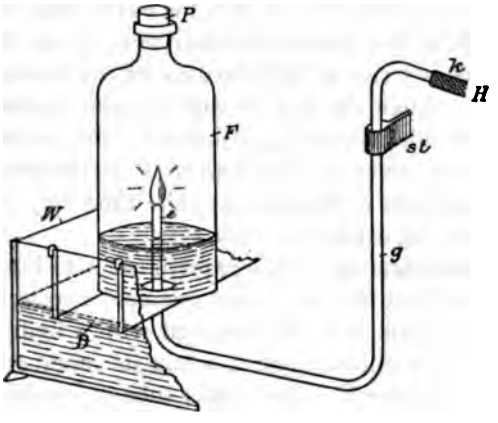


Fig. 1.

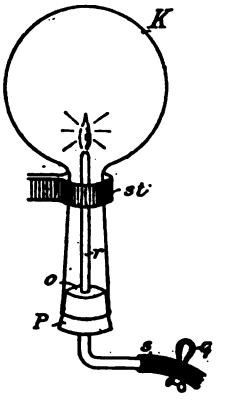


Fig. 2.

I. A glass tube bent as shown in Fig. 1 is joined at *k* with a Kipp hydrogen generator. The part of the tube marked *e* (the end of the tube should not be drawn out of the jet) is pushed up through a hole in the bridge of a pneumatic trough. Hydrogen is passed through the tube and lighted, the flame at first being made as small as possible. A bottle F (about 12 cms. in diameter and 36 cms. high), with its bottom cut off, and closed with a rubber stopper P, is set down on the bridge over the flame which is at once made somewhat larger. The position of the tube *g* held at the clamp *st* of a stand is so regulated that it reaches only about 2 cms. above the water which may rise in the bottle. The flame burns as usual for a short time, then becomes pale-blue, and finally colorless. It is, nevertheless, possible to tell just when the flame goes out, and the instant this takes place, the current of hydrogen must be stopped. The water, which has already risen

somewhat, now rises rapidly and in a little while reaches the same height it would in an experiment with phosphorus. The removal of the oxygen by means of burning hydrogen has the advantage over phosphorus not only in its great simplicity, but also in there being no dense fumes formed which must be allowed to settle before the residual gas can be shown to be nitrogen.

II. Later, when illuminating gas or the phenomena of combustion are being studied, this experiment may be repeated, and the position of the water level marked. If then the experiment be performed with illuminating gas instead of hydrogen, it can be shown that the water does not rise as high because of the formation of carbonic acid gas. Attention may be called to the characteristic lengthening of the illuminating gas flame; it also seems to be particularly sensitive, since if the stopper P be inserted quickly, the flame is sometimes extinguished. The tube may be quite small, but should not be drawn out into a jet.

III. An interesting modification of this experiment is to burn the hydrogen in a flask without the aid of any pneumatic trough. An L-tube *r* (Fig. 2) of 4 mm. bore is connected with a hydrogen generator by means of a rubber tube *s*, while its other end passes through the rubber stopper P. The rubber tube is provided with a pinch cock *q*. The stopper fits in a flask of about one liter capacity, of not too thin glass and supported by means of a clamp *st* on a stand. The rubber stopper and *r* are lowered out of the flask, hydrogen passed and lighted. The flame is made very small at first, and the narrower end of the stopper wet with water from a wash bottle, so as to insure an air tight joint when the stopper is inserted in the neck of the flask. The flame behaves just as in the preceding experiment, and as soon as it goes out, the pinch cock *q* is closed. The end of the tube *s* is placed in a vessel full of water, and when the apparatus is at the temperature of the room, the pinch cock is slowly opened. The water gushes in and soon fills the flask one-fifth full. The experiment is totally devoid of danger in spite of the heat of the flame.

IV. The last experiment may also be performed with pure oxygen. The air is displaced by a current of oxygen, the flask is closed with a rubber stopper, inverted and fixed in a clamp just as above. The jet of hydrogen is ignited, the solid stopper re-

moved and the flame pushed up into the flask as rapidly as possible. The flame continues to burn for about eight minutes. At first it becomes smaller and even passes down a few centimeters into the tube. Shortly before it goes out, it lengthens again, and it is advisable to shut off the current of gas a little. The flask is allowed to cool slowly, and then the pinch cock is opened very gradually. A little gas is always left in the flask, the nature of which may be established as follows: The tube r is drawn almost through the stopper P, the flask is set upright, and a solid stopper quickly substituted for P. The flask is supported on a stand, a blazing splinter of wood brought to its mouth, and the stopper removed. The explosion which ensues shows that the most of the residual gas is hydrogen, which must have entered when the flame was just on the point of going out.

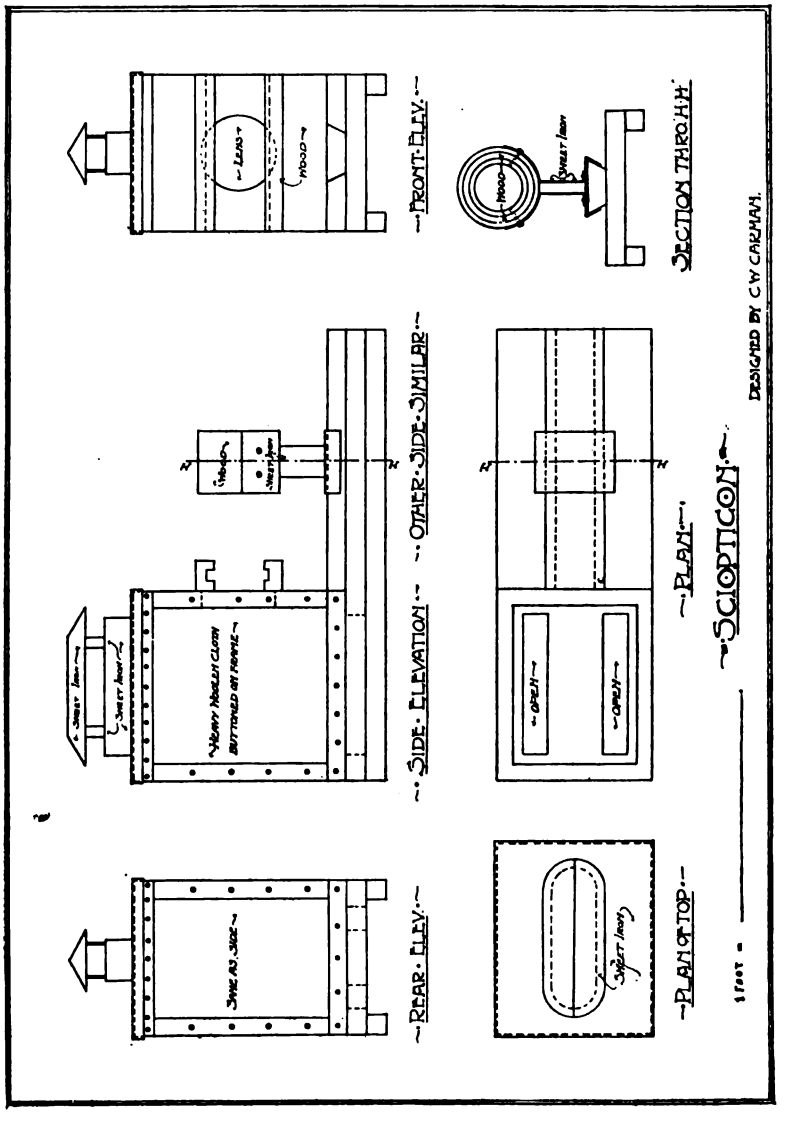
A SIMPLE FORM OF SCIOPTICON.

BY C. W. CARMAN.
Department of Physics, The Chicago Institute.

It happens not infrequently that the teacher in a small town finds that his work could be made more profitable and interesting by the aid of some form of projecting apparatus. The appropriation for such purposes, however, is often found to be too limited to permit of the purchase of the cheapest lanterns furnished by the regular manufacturers. Several times the writer has found himself confronted by such conditions. Rather than to do without the piece of apparatus, even in its crude form, one has been constructed in the laboratory.

Hoping to aid any one who may wish to know the necessary expense and a method of construction, working drawings, specifications and an estimate are here submitted. If the instructor should not have laboratory facilities sufficient to do the work himself, the carpenter and tin-shop will furnish the same at very small expense.

Though it is not to be presumed that the best results can be obtained from the apparatus described below, it is believed that


~REAR ELEV.~
~SIDE ELEVATION~
~OTHER SIDE SIMILAR~
~FRONT ELEV.~
~PLAN OF TOP~
~PLAN~
~SECTION THRO H H~
~SCIOPTICON~
DESIGNED BY C.W. CARHART.

one who secures all results that are possible from it will find himself well on the way to the possession of better apparatus.

Specifications.—The apparatus consists of a pine board 24 inches long and 8 inches wide, resting upon two strips 1 inch square and 24 inches long. On one end of the board a rectangular frame, 10 inches long, 8 inches wide and 11 inches high, is built out of pine strips 1 inch square. Extending from this frame along the center of the board to the other end is attached a guide for the objective support. The front of the frame is closed by a board one inch thick, in the center of which is a 4½-inch opening for receiving the condensing lens. Grooved strips are secured on the front to serve as a slide-holder. The sides and rear are closed by means of woolen cloth buttoned on the frame. The objective support is constructed of sheet-iron and a hollow wood cylinder. The top is constructed from sheet-iron in a manner clearly shown in the drawings.

Three boards 2 feet long and 1 foot wide, fastened together at the ends by means of hinges, in such form as to make an adjustable letter "Z," is a convenient and cheap support by means which the height of the sciopticon can be regulated.

The following is an estimate of the expense required:

Lumber, screws and carriage buttons	$0.30
Sheet-iron top and objective support	1.50
Condensing lenses, mounted	2.00
Objective lens, mounted	3.00
Oil lamp with reflector	0.50
Cloth for sides and screen	0.60
Total	$7.90

The apparatus may be converted into an heliopticon for the additional sum of $5.00.

Other forms of illuminants may be obtained at the following prices: Acetylene outfit, $16.00; lime light burner, $6.00; incandescent electric lamp, $2.50; incandescent gas burner, $1.00; arc lamp, $8.00.

The most desirable form of illuminant depends upon the locality in which the apparatus is to be operated. Electricity is the cheapest and most satisfactory, if it can be obtained.

Notes.

ZOOLOGY.

In studying infusoria it is customary to feed them powdered carmine, that the food vacuole formation and movement may be seen. Frequently the results with ordinary powdered carmine are unsatisfactory on account of the little which is taken. Much more striking results are obtained with using *water color carmine*, such as is employed by artists, and is to be had in little porcelain cups. A very small quantity is rubbed in a drop of water on a slide and the infusoria added.

Detroit Central High School. L. MURBACH.

Slowing of the Movements of Infusoria. In our work the method of using cotton to keep infusoria in the field of the microscope has been far from satisfactory. A solution of gum arabic has been found to answer very well. By using the proper strength of solution the movements of the infusoria may be slowed to any desired degree. While the cilia continue to vibrate, the rate of vibration is much lessened, so that they may be seen without much difficulty.

Lee, in the "Microtomists' Vade Mecum," states on the authority of Eismond that peach gum may be used for this purpose, but that gum arabic will not do. I do not understand how such a conclusion has been reached. We have employed gum arabic successfully for this purpose for several years. The chief advantage of gum arabic lie in the fact that it is easily soluble in cold water, while peach, cherry or plum gum must be boiled in water and be diluted to the proper consistency.

Lake View High School, Chicago. E. A. BEDFORD.

Study of Earthworms. Glass tubing of a diameter slightly larger than that of the earthworm is fashioned in a flame into tubes closed at one end and about 20 cms. (8 in.) long. In these are placed entire earthworms previously killed in the usual manner. The remaining space is filled with a 3 per cent solution of formalin. The tube is closed by inserting a cork, which is cut off even with the edge of the glass. Then the whole end is covered with sealing wax.

Earthworms from which the dorsal body had been removed to show the alimentary canal and the dorsal blood vessel were also placed in tubes. Also earthworms from which the alimentary canal had bee nremoved to show the nerve cord.

These tubes were found to be of great value used in connection with the other material for the study of the worm.

Lake View High School, Chicago. H. A. BEDFORD.

To Study the Mouth Parts of the Crayfish, the appendages of one side are sewed in their proper order to a strip of stiff linen paper, which must not contain any glue. This is placed in a screw-topped vial about 13 cms. (5 in.) high and 2 cms. (¾ in.) in diameter, and the vial filled with a 3 per cent solution of formalin. Some of the advantages of this method are that the appendages are always in good condition; they are not injured by handling; they are always in their proper order and they may be kept indefinitely.

In my classes these preparations are used chiefly in connection with the study of the living crayfish. The pupil first studies the appendages in a vial. He then determines their positions on the crayfish and observes their use when the crayfish has been placed in a jar of water, especially while the crayfish is eating. After the pupil has finished the study of the other appendages and is prepared to trace the homology of the different appendages he has the mouth parts in good condition for study.

The results obtained in my classes have been much more satisfactory than those obtained by having the pupil remove the mouth parts of a dead crayfish.

Lake View High School, Chicago. H. A. BEDFORD.

BIOLOGY.

Effect of Extreme Cold on Vitality. As by the aid of liquid air and hydrogen very low temperatures can be produced and maintained for some time, several investigators have subjected seeds, ferments, bacteria, etc., to the action of these low temperatures with a view to ascertaining the effect on their vitality. Thus Pozerski (Comptes rendus de la Société de Biologie, LII., p. 714, 1900) placed a number of soluble ferments in three separate sets of test tubes; put one set in liquid air at a temperature of —191° C.

for forty-five minutes, kept a second set at ordinary temperatures and boiled the third set. Equal amounts of the ferments from each set were then mixed with the same amount of the substance to be fermented, and all allowed to stand at 40° C. for the same length of time. It was found that the cooling had had no perceptible action on the ferments.

Allan MacFadyen (Proceedings of the Royal Society of London, LXVI., p. 180, 1900) describes the following experiment: "Fifty liters of the laboratory air about six feet from the ground were liquified at atmospheric pressure in a glass bulb by means of boiling liquid air *in vacuo*. The temperature reached was about —210° C. The bulb was then sealed off, the contents being still at a temperature below zero, and was subsequently opened and washed out with sterile broth. A series of plate cultures were made from the broth in nutrient gelatine, agar-agar and sugar agar, and were incubated under aërobic and anaërobic conditions at 22° and 37° C. for a period of ten days. The anaërobic plate cultures remained sterile. The aërobic plates yielded forty-four organisms, which had survived an exposure to —210° C. The organisms were representative types of those met with in the air, viz., molds, bacilli, cocci, tortulae and sarcinae."

Sir William Thistleton-Dyer (Proceedings of the Royal Society of London, LXV., p. 361, 1900) had a half dozen representative lots of seeds "soaked in liquid hydrogen" for six hours, and yet they "did not show the smallest visible trace of the ordeal to which they had been subjected. They were sorted out and immediately sown," and all without exception germinated.

GEOLOGY.

A group of papers in the Transactions of the American Institute of Mining Engineers, Vol. XXX, 1900, upon the nature of the deposition and the classification of ores presents many points of general interest.

These are: The Origin and Classification of Ores, by Chas. R. Keyes; Some Principles Controlling the Deposition of Ores, by C. R. Van Hise; Secondary Enrichment of Ore Deposits, by S. F. Emmons; Enrichment of Gold and Silver Veins, by Walter H. Weed.

The first of these is an attempt to classify the ores upon the geological control of their deposition and form. As will be seen by the following table which sums up the classification, the scheme regards as more important the geological occurrence of the ores than the nature of their formation:

CLASSIFICATION OF ORE DEPOSITS.

Groups.	Categories.	Miners' Forms.
I. HYPOTAXIC. Mainly surface deposits.	Aqueous transportation.	Placers.
	Residual cumulation.	Pockets (in part).
	Precipitative action.	Bog-bodies, some beds, layers.
II. EUTAXIC. Chiefly stratified formations.	Original sedimentation.	Beds, strata, layers.
	Selective dissemination.	Impregnations (in part).
	Emponded amassment.	Masses (in part), some segregations.
	Fold-filling.	Saddle-reefs.
	Crevice accretion.	Gash-veins, stock-work (in part).
	Concretionary accumulation.	Nodules.
	Metamorphic replacement.	Fahlbands (in part), beds.
III ATAXIC. Predominantly unstratified and irregular bodies.	Magmatic secretion.	Masses (in part), some lenses.
	Metamorphic segregation.	Stocks, lenses.
	Fumerole impregnation.	Contact-veins, some impregnations.
	Preferential collection.	Chambers (in part), some pockets, linked-veins.
	Fissure occupation.	Attrition-veins (in part), some linked-veins, true veins.

The second paper, by Professor Van Hise, has been published in a somewhat less extended form as an address before the Western Society of Engineers, at Chicago, in the journal of that society for December, 1900, and in the Journal of Geology for November-December, 1900.

The paper deals with the movements of underground waters and their action on the ores. The deposits are the result of two concentrations; the first by ascending waters and a second by descending waters actuated by gravity and acting through the zone of weathered and fractured rocks. Deposits are arranged in three classes: Ores of igneous origin; ores which are the direct result of processes of sedimentation, and ores which are deposited by underground waters.

The last class is the only one considered by the paper, and is divided as follows:

"(a) Ores which at the point of precipitation are deposited by ascending waters alone. These ores are usually metallic or some form of sulphuret; but they may be tellurides, silicates, or carbonates.

"(b) Ores which at the place of precipitation are deposited by descending waters alone. These ores are generally oxides, carbonates, chlorides, etc., but silicates and metals are exceptionally included.

"(c) Ores which receive a first concentration by ascending waters and a reconcentration by descending waters. The concentrating by ascending waters may wholly precede the concentration by descending waters, but often the two processes are at least partly contemporaneous."

The last class is regarded as by far the most common.

Professor Emmon's paper covers somewhat the same ground as regards the action of ground waters and the local concentration of ores by descending water. His remarks upon the relation of the physiographic and climatic changes are of especial interest. He says:

"Active degradation favors the accumulation of enrichment, while prolonged degradation of a region, resulting from physiographic revolutions, may result in successive migrations of material and the accumulation in a relatively shallow zone of the metals derived from many hundreds, and possibly thousands, of feet of the vein worn away in the degradation of the land. Climatic conditions, rainfall or aridity, warmth and rapid alteration of vein fractures, are agents affecting surface weathering, and hence, also, enrichment.

"Active degradation of a region, that is, rapid weathering, favors enrichment by the quickness with which it removes the upper already leached part of the vein, so that a larger amount of the vein-matter is lixiviated in a given time than would result from the slower wasting of the land. Such enrichments are favored by high latitudes. Moreover, the mountainous regions are those in which secondary fractures are most apt to be found.

"Prolonged degradation is favorable for a similar reason, since time is a factor in enrichment and changes in elevation, etc., affect the rate and the progress of decay of the vein; while the crustal movements accompanying the physiographic changes favor fracturing of the earlier deposit, increasing facility of leaching and place for deposition. If a region passes through several cycles of erosion and elevation, it is evident that their result is likely to be a succession of enrichments in which not only the original ore is leached, but the earlier enrichment deposits migrate downward. At Butte, Mont., the region has passed through several very pronounced changes in elevation since the formation of veins in Tertiary time.

In early Tertiary time the present topography of the region was blocked out, and mountain ranges and deep valleys carved. This was succeeded by earth movements by which the streams became clogged or the valleys dammed, forming lakes; while volcanoes broke out at numerous places and showered ashes and scoria over the region. The valleys were silted up or in part filled with volcanic débris before crustal movements drained the valleys and altered the divides. More recent movement, possibly still continuing, is marked by faults and a reversing of the stream courses. The old valley at Butte is filled by hundreds of feet of débris, and a mountain wall 2,500 feet high marks a north and south fault-line. These changes all caused a migration of water-level facilitating the processes of weathering and enrichment, and the great bodies of rich copper ores of the region are believed to be in part due to this cause."

In all the papers there is a complete agreement upon the fact that the deposits are largely superficial in nature and due to secondary processes of concentration.

State Normal School, Milwaukee, Wis. E. C. CASE.

CHEMISTRY.

Hydrogen and Hydrocarbons in the Atmosphere. A. Gautier has found that 100 liters of air collected on the streets of Paris contain 19.4 cc. of hydrogen, 12 cc. of methane, 1.7 cc. of benzene and its homologues, and 0.2 cc. of carbon monoxide and other hydrocarbons. Air collected over the sea and in forests always contains hydrogen, although in somewhat smaller amounts. According to the kinetic theory of gases, the molecules of hydrogen are so light and have such rapid vibratory motions that they escape from the atmosphere into interstellar space. As a matter of fact, large quantities of hydrogen are introduced into the atmosphere by volcanoes and through decay of vegetable and animal substances. Volcanic rocks, and especially granite, give off hydrogen in abundance when heated with acids or even water. If, then, the hydrogen did not pass out of the atmosphere almost as soon as produced, the relative amount of it would be much greater.

Hydrogen for Illuminating Purposes. Hydrogen prepared by electrolysis is threatening to supplant acetlyene. Dr. Schmidt of Switzerland finds that the light given out by hydrogen burning in a mantle (as in a Welsbach burner) costs per candle power less than one-half what acetylene does. Furthermore, hydrogen yields no carbonic acid gas, is not poisonous and uses less oxygen than any other illuminating gas. It is also claimed that the danger of

explosion is much less than with acetylene. The electrolysis is carried out in iron vessels with iron electrodes, the electrolyte being a solution of a caustic alkali.

Preparation of Ozone. When oxygen is formed in a chemical reaction taking place at low temperatures it shows a tendency to polymerize and produce ozone. Such is the case in the reaction of sulphuric acid on barium dioxide or potassium permanganate. But even at temperatures not higher than the ordinary, ozone is more or less completely changed into oxygen. In 1891 Prof. H. Moissan showed that water is decomposed by fluorine with formation of hydrogen fluoride and ozone, and when single drops of water were made to fall into an atmosphere of fluorine the formation of ozone was so abundant as to be easily recognizable by its blue color. Recently Professor Moissan (Comptes Rendus, CXXIX., p. 570, 1899) has studied this matter more thoroughly, and has found that when a rapid current of fluorine is passed into water kept constantly at 0° C., a gas is obtained containing 14.39 per cent by volume of ozone. When not more than three liters per hour were passed into the water the ozone was only 10 to 12 per cent of the volume of the oxygen; and when the temperature rose above 0° C. the proportion of ozone was considerably less. It seems that it is perhaps possible to make use of this reaction to prepare ozone on a large scale for industrial purposes.

The Boiling Points of Zinc and of Cadmium are often chosen as fixed points in the measurement of high temperatures, and D. Berthelot therefore undertook to determine them as accurately as possible. (Comptes Rendus, CXXXI., p. 380, 1900.) Specially constructed electric furnaces were employed in which the heating was done by means of a current passing through nickel wires. The metals were prepared very carefully, so as to assure the highest degree of purity. The boiling of zinc was found to be 920° C., agreeing well with Holborn and Day's value (920° C.), as well as Callendar's (916° C.); Cadmium boiled at 778° C. differing somewhat from the older values; Becquerel (746° C.), Carnelly (763° C. to 772° C.), and Deville and Troost (815° C.).

Radioactive Elements. The property that uranium and thorium compounds have of sending out in the dark, without previous exposure to light, rays which act upon photographic plates, cause air to conduct electricity and excite phosphorescence has in the last few years received a good deal of attention. A similar radioactivity has been observed in compounds of barium, bismuth and titanium prepared from pitchblende and substances of presumably elementary nature, as radium and polonium have been obtained. Quite recently radioactive lead and radioactive compounds belonging to the rare metals of the cerium and yttrium groups have been isolated, which, when completely separated from uranium, thorium, barium and bismuth, still preserve their radioactivity. When the active lead salts are transformed into lead oxide their radioactivity is increased, just as is also the case with thorium and uranium.

Those who are interested in "radium" will find exhaustive accounts of this remarkable substance—perhaps element—in (1) *Popular Science Monthly,* July and September, 1900; (2) *Journal of the American Chemical Society,* September, 1900; (3) *Physical Review,* September, 1900.

A Statue of Lavoisier was unveiled in Paris on July 27, 1900. It stands in the Place de la Madeleine, facing the Rue Tronchet, near the house where Lavoisier lived for many years. The fund for the monument, amounting to 98,000 francs, was raised by international subscription. The dedicatory exercises were arranged by the French minister of public instruction, who accepted the monument for the city, the presentation address being made by M. Moissan. The bronze statue of the famous chemist, which was made by M. Barrias, stands upon a granite pedestal; the latter is ornamented by two bas-reliefs, one representing Lavoisier dictating an experiment to his wife in his laboratory, the other showing him in the act of expounding the result of some experiments to his colleagues at the French Academy. The dedicatory address was to have been made by M. Berthelot, but he was detained by illness. The monument is fittingly inscribed with a single sentence, which sums up Lavoisier's work: *"Fondateur de la chimie moderne."*

Lowell, Mass. LYMAN C. NEWELL.

Book Reviews.

Popular Astronomy, being the new descriptive Astronomy by JOEL DORMAN STEELE, Ph.D., revised and brought down to date by MABEL LOOMIS TODD. 13x19 cms., 349 pages. American Book Co., New York. 1900. $1.00. Judging from external appearances alone, we should scarcely recognize in this book under its new cover and new title a revision of Steele's *"Fourteen Weeks in Astronomy."* Upon turning the leaves, however, the old illustrations are seen to be generally retained, and a more careful examination shows that the plan of the old book has been quite strictly followed throughout. Nevertheless, the revision has been conscientious and thorough. The full extent of the changes necessary to bring the work strictly up to date, and to correct much that was unscientific in the old book, can be realized only by a careful comparison of the old with the new. In numerous instances paragraphs have been recast so as to render obscure and unscientific statements lucid and accurate, while minor verbal changes are almost innumerable.

Now and then one could wish that Mrs. Todd had been more radical in her work of revision, as, for instance, where she retains the useless distinction between the "sensible" (not visible) horizon, and the "rational" horizon. All of the important advances in the science during the past fifteen years receive due attention for a work of this scope. While most of the old illustrations have been retained, they have generally been made from new cuts. Several of the "less worthy" illustrations have given place to better ones, and a number of new illustrations have been added—notably a series of views of the solar corona, and a series of drawings of the surface of Mars.

As a result of Mrs. Todd's labors, we have an easy, popular work, at once teachable and scientific, well adapted to the needs of the smaller high schools which can devote but a limited amount of time to the study of the science.

Hartford, Conn. B. S. ANNIS.

A Brief Course in General Physics, Experimental and Applied. By GEORGE A. HOADLEY, A.M., C.E., Professor of Physics in Swarthmore College. 13x19 cms., 463 pages. American Book Co., New York. 1900. $1.00. This is a book of reasonable size, treating the subject to about the extent usual in books intended for secondary school use. The method of treatment is that of presenting the facts, illustrating by demonstrations and providing laboratory work and problems to emphasize the facts and concepts already obtained. By this method the laboratory work would appear to be placed in an inferior position.

The order of the topics is the usual one—Properties of Matter, Mechan-

ics of Solids, Liquids and Gases; Sound, Heat, Magnetism, Electricity and Light—and the proportion of space assigned to each is fairly divided. As a clear, well balanced presentation of the subject, the book is to be commended.

In matters of detail, the illustrations are mainly well chosen and executed, the general arrangement is good and the text is clear.

As is common with books combining text and laboratory instructions, the latter are too condensed in many cases to enable pupils to do the work without considerable aid, either oral or written, from the teacher, and some of the experiments, such as those calling for a buzz-saw or a lathe, would be rather difficult to carry out in an ordinary school. Much of the work would have to be done individually and could not be done by class-sections at the same time. The descriptions of several demonstrations are a little careless; for instance, in Experiment 6 (page 23), it would seem that the heat of the burning phosphorus would cause such an expansion that a part of the gas would escape.

It is to be regretted that more space could not have been devoted to the practical applications of the principles of physics, the treatment given to electricity being perhaps an exception.

To those desiring to teach physics according to the methods chosen, basing the work on presentation and illustration, the book is to be commended; to those preferring the more individual methods, in which the laboratory is made a basis for work, the book will probably not appeal.

The High School, New Bedford, Mass. CHARLES R. ALLEN.

Experimental Chemistry. By LYMAN C. NEWELL, Ph.D.(Johns Hopkins), Instructor in Chemistry at the State Normal School, Lowell, Mass. 13x19 cms., xv and 410 pages. D. C. Heath & Co., Boston. 1900. $1.10. Of the numerous elementary chemistries published in recent years, not one has been presented to the teaching body in a neater style than this, and hardly one has departed farther from the established formula of presenting the subject. With a strong belief that a text-book is not a field from which to glean facts, the author presents a guide book to the student of chemistry, and in all cases where possible the student's work is put upon a foundation of experimentation.

The book would guide the student at first through a series of quantitative experiments with the elementary gases, requiring much skill in setting up and arranging complicated apparatus as well as in its manipulation. In many cases, also, apparatus is called for which on account of expense is not ordinarily found in the laboratories of even our best high schools.

The usual custom has been to regard experiments requiring accurate weighing and much apparatus as serving the best purpose of the student after he has gained some skill in handling chemical ware. While by the author's arrangement the student will be led to do careful work and to be more exact in his experiments, and thus be made to comprehend more clearly the object of his experiments, is it not true that in the case of the

average student more interest will be aroused by giving him some striking facts at the beginning and having him do some experiments where correct results are bound to result, notwithstanding the perverseness of nature and the lack of skill of the workman?

An excessive amount of time would seem to be required to complete the book, more, indeed, than can be given to the subject to chemistry in most high schools. If a pupil arranges his own apparatus, many of the experiments will take more than two hours, and if a school has three or, at best, four hours per week for laboratory work, certainly one hundred and thirty periods of laboratory work will prove insufficient. In addition, according to the methods of the best teachers, an equal amount of time will be required by the pupil to make drawings of his apparatus and for a clear exposition of his laboratory work in his note book. The description of the elements which is generally given in most text books is left to the pupil to be garnered from various sources. At the end of each chapter there are given class-room exercises, fifty-three in all, and each containing thirty to fifty questions, so the pupil will gain a great deal of experience in delving into the tomes of a chemical library containing some seventy-five suggested volumes; but all this takes time. The recitation on the laboratory work will require, say, an hour per week; at least two hours per week will be necessary to eliminate the chaff gathered with the wheat for the class work and one hour per week for a lecture, a complemental factor of some eight hours of school time. Stoichiometrical problems fairly bristle in every part of the book. Surely the additional time required to do these will bring the sum total to ten periods of recitation a week.

In addition to the time occupied in schools, there is hardly a doubt but that all a pupil's skill and ingenuity will be required not to make the study time devoted to chemistry out of school greater than in school. With several other studies, all of this time is quite out of the question.

In some ways, however, this is certainly an ideal book. It does not enter into the discussion of chemical compounds which are chemical curiosities, and it confines itself to the simple facts and theories of the usual courses in chemistry; but, as indicated above, in very few schools would there be the ability to complete the entire work, and it is so bound into a comprehensive totality that one cannot omit a single part of it without impairment of the whole. To any pupil who has developed a special adaptation for scientific work, this book will give an excellent training, and to normal students who have as their aim to prepare themselves in chemistry for a major study no book could better serve as a teacher's compendium and guide. If, too, a college student intends to try for honors in chemistry, this book will guide him through a valuable course, and it is just the book a college student needs to help clarify the usual lectures in descriptive chemistry. To teachers and embryo chemists this book should prove exceedingly helpful. The experiments are many of them new and simple, and hence valuable, and the progressive manner of presenting the subject suggests many new thoughts

to all. As a whole, the book tends to change our ideas and modify our methods and thus bring us nearer the needed Utopia.

North Division High School, Chicago. C. E. BOYNTON.

Laboratory Instructions in General Chemistry. Arranged by ERNEST A. CONGDON, Professor of Chemistry, Drexel Institute, Philadelphia. 14x21 cms., 110 pages. P. Blakiston's Sons & Co., Philadelphia. 1901. $1.00. Directions for the performance of 262 experiments of almost exclusively qualitative nature are given, to be used in connection with any standard text. In an appendix are directions for about a dozen quantitative experiments.

The directions are usually but bare outlines, and not an inconsiderable amount of preliminary demonstration and oral instruction is undoubtedly necessary on the part of the teacher to insure the student's performing the majority of the experiments successfully. Also quite an elaborate outfit of chemicals, apparatus and reference books is required.

The book is well printed and the numerous cuts are excellent; it is bound up with blank pages for notes.

For schools with well equipped laboratories and giving a rather more advanced course in General Chemistry than is customary in most high schools, this book will be found of much value.

C. E. L.

A School Chemistry. By JOHN WADDELL. 13x19 cms., xiii and 278 pages. The Macmillan Co., New York. 1900. $0.90. The evolution of the modern text book for laboratory studies in secondary schools has been very rapid in late years. The first books developing chemistry along this line were almost entirely qualitative and descriptive, the facts presented being in no essential particular especially calculated to furnish the basis of theory, while the idea of quantity appeared in the *discussion* of theory only. In fact, as Dr. Waddell says in his preface (referring to the impressions of beginners), "The theories do not seem to arise from the facts. If any connection is regarded as existing between the two, the theories are supposed to be the more fundamental," etc.

In the effort to correct this obvious fault, some of the recent books have undertaken to develop the entire subject in a purely quantitative way, practically ignoring the descriptive and qualitative phases. In most cases, these ultra-modern books are bound to have very little following, as the experiments as a whole, and many of the discussions are too advanced for the class of minds to be reached.

In the opinion of the writer, the successful books, and in the nature of things there is room for more than one, will be those which cover the essential points of theory-development, together with a wholesome amount of the descriptive and qualitative side of the subject.

Dr. Waddell has brought into the space of 278 pages a vast amount of descriptive and historical detail which are very essential to the beginner. It is a question whether he has not overdone this. At the same time, he

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a clay pipe as a sulphur dioxide generator, the burning sulphur in the bowl being continuously supplied with air through the stem; (3) to a convenient support for a glass graduated cylinder made by setting the graduate in a base made from a tin cover filled with plaster of Paris and coated with asphalt paint, and (4) to the efficiency of hair curlers in cutting glass, the wooden handle allowing the tongs to be used when hot.

After the banquet there was a symposium on Laboratory Notes. The following topics were discussed by thirteen members: (1) Special value of laboratory notes to student and teacher. (2) Should complete notes be written in the laboratory, or no notes or very brief ones there, and fuller ones outside, and should students be allowed to take note books from the laboratory. (3) How fully ought apparatus and operations to be described, should ink or pencil be used, and should drawings be required. (4) The main points to be brought out in notes and how full ought the final notes to be. (5) Methods of examining and marking notes. (6) Subsequent discussion of laboratory notes with students.

The papers presented on these topics were carefully prepared, and were of such vital interest that their contents will be reserved for fuller treatment in subsequent numbers of School Science.

Reported by Lyman C. Newell.

Correspondence.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion as well as answers to the questions of others. Those of sufficient merit and interest will be published.

1. Is there not a flaw in the statement commonly made that "children are natural observers, and that later school life educates the observing powers out of them"?

2. Considered from the biological standpoint, what constitutes a "good drawing"?

Which is the better criterion by which to judge of a student's work in biology—a good drawing or a good description?

4. Given one or two hundred wires from 15 cms. to 2 ms. long, some straight, some coiled, and of gauge numbers ranging from 16 to 30 B. & S. What is the best way to keep them from getting tangled, and yet have them accessible and in a small space?

5. Suppose a class has been made somewhat familiar with the conception of electrostatic potential—what is the best way to link to this electromotive force and difference of potential in electrokinetics?

6. What minerals are suitable for "unknowns" in elementary qualitative analysis?

7. To what extent should other indicators than litmus be used in the elementary study of acids, bases and salts?

8. To what extent should the English of laboratory notes be corrected by the science teacher?

9. What experiments best show that sulphuric acid is not as "strong" an acid as hydrochloric or nitric acid?

10. What proportion ought to be given to morphology, physiology and ecology? Does either possess superior educational value?

BUREAU OF INFORMATION.

E. F. L. writes: "I have observed that when magnesium is heated in a porcelain crucible, there is often produced a small amount of a brownish black substance which forms a hard and shiny crust in the lower part of the crucible. Sometimes it sticks so tenaciously to the crucible that it cannot be removed, and it does not dissolve in any acids, not even nitro-hydrochloric. Will you kindly inform me as to the nature of this produce, how to prevent its formation, and how to remove it, when once formed"?

Ans. The substance is silicon derived from the porcelain by the reducing action of magnesium. There may also be formed compounds of silicon and magnesium, and of magnesium and nitrogen, but these are decomposed by acids. The magnesium should be heated very gently, and as free access of air as possible provided for, but even then there is no certainty that the substance may not be formed. The crucible may be cleaned fairly well by boiling it out for some time with a strong solution of caustic potash.

R. K. writes: "I teach science and German here, and would like to get hold of some good periodical in German that treats of scientific topics much as SCIENCE in this country does. Will you be so kind as to recommend to me such a journal, and also tell me how to order it"?

Ans.—Naturwissenschaftliche Rundschau, Friedr. Vieweg & Sohn in Braunschweig, publishers; 4 marks per quarter. Any good book dealer ought to be able to order it for you.

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School Science

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THE DEMAND FOR SCIENCE TEACHERS.

BY STRATTON D. BROOKS.

High School Visitor and Assistant Professor of Pedagogy, University of Illinois.

There is no subject which suffers more from lack of adequate preparation on the part of the teacher than does science. In some subjects a determination to succeed and a persistent effort to master the difficulties will, in a measure, alleviate the ills arising from insufficient acquaintance with the subject matter. In science teaching, however, these will not compensate for a lack of thorough scientific training. The teacher who has not had this training has missed the spirit of scientific investigation and, what is worse, he usually does not know his lack. He deals with the facts of science, teaches things which are curious or interesting because unfamiliar, and behind a multitude of more or less useless facts hides his own entire lack of conception of scientific progression, scientific unity, scientific spirit.

That the need of specially prepared teachers who have had thorough training in some one line, together with some instruction in the best method of teaching, is recognized by those who select teachers for the high schools of Illinois, is shown by the nature of the requests recently made for teachers. Seventy-eight such requests were sent in, of which sixteen were for high school principals, and fifty-two for high school teachers. But ten failed to specify the subjects or mentioned more than two lines of work. These ten were either for superintendents who were not required to teach or for high school principals in small schools where nearly all of the work is done by the one teacher.

Of the seventy-eight requests, twenty-five were for science

teachers, showing that superintendents and school boards recognize the necessity of a special teacher of science. Sixteen of these twenty-five requests were for teachers of science alone (twelve for general science, three for biology, one for physics and chemistry). The small number for physics and chemistry arises from the fact that these subjects occur in the third and fourth years, and but few schools are large enough to have more than one class in each. The teacher of physics and chemistry, therefore, must teach other subjects, usually the other sciences, in which case the request was for a teacher of general science. The other combinations were as follows: Science with mathematics, 4; science with English, 2; biology with mathematics, 1; biology with art, 2.

Another interesting thing noted was the strong demand for women who could teach science. This probably arises from the fact that men who teach science usually can command higher wages than teachers of other branches. Many schools have, therefore, been unable to pay for a special teacher, and the work has been divided among the other teachers. The folly of farming out the science to the teacher who happens to have a vacant period is becoming apparent, and from the effort to correct this condition a demand for cheaper teachers has arisen. Because the wages of women are lower than those of men the requests frequently specify that a woman is preferred. This should not be taken to signify that wages for either men or women are decreasing. It simply means that more places for science teachers are opening and that many of these are being filled by women, usually at salaries larger than these same women could command in other lines of high-school work.

The following tabulation shows the demand for the different subjects. Each combination is given under both subjects:

Position wholly or partly science, 25; mathematics, 18; English, 13; Latin, 11; German, 5; history, 5; art, 2; Greek, 2; commercial work, 1; not specified or general, 10; requiring athletes, 5; requiring military, 1.

From this it appears that there is a stronger demand for trained teachers of science than for teachers in other lines. This arises from the fact that the other branches have been taught

longer and have a better established place in the school program of studies. More teachers, therefore, are prepared to teach them and there is less need for the superintendents to apply to the university for special teachers in these lines. Furthermore, there are more places able to prepare teachers of Latin or mathematics than there are fitted to give proper training to teachers of science, and while there are more places for teachers of Latin or mathematics, the requests for these are spread over more colleges and universities. Doubtless there are colleges where the requests for teachers would show a much lower percentage of science teachers.

It is a pleasure to note the rapidly improving condition of science teaching in this State. It is evidence of great good to come that so many schools are seeking special science teachers. One good thing demands another. A good science teacher must have a laboratory room and *will get it.* A laboratory calls for equipment and equipment insures better results. Schools which have been for years placidly content with an air pump and a frictional electrical machine have awakened to the fact that these do not make a laboratory. Of the eighty-nine schools visited last year, five have added a room for a laboratory, and eighteen have made large additions to their science equipment in the line of individual quantitative experiments. The others already had a fair equipment. If a proportional improvement was made in the schools not visited, there is certainly hope for much excellent science work.

FOREST BOTANY.

BY W. H. MULDREW, B. A., D. PÆD.
Principal of the High School, Gravenhurst, Ontario.

Educators continue to differ as to whether the better training, from an educational point of view, is to be gained in connection with subjects of utilitarian value or those of more strictly academic character; and there may well be advantages on the side of the latter such as are not associated with the facts of everyday

life. But whatever may be his opinion on this broad question, the teacher of science in a secondary school must appreciate the importance of relating his work to the previous knowledge and interests of the learner. The youth of thirteen has already acquired an immense body of facts concerning the physical world, which, if assimilated in due relation would form a very respectable foundation for the teaching of natural science; and when the formal treatment of this department is begun in secondary schools, it becomes an interesting question how best to use this general basis as a stepping stone to higher attainments. The first term of formal science should be rather an exodus than a genesis. How shall we best make the transition from the mass of disjointed scraps of information to that organized knowledge which deserves the name of science?

The ideal course would furnish ample material for observation and for the use of observations in reaching conclusions, and it would deal with materials that are familiar and of previous interest. It would put the learner, almost from the beginning, in a position to work with a minimum of help from the teacher and it would not hamper him with foreign difficulties such as a too frequent use of technical terms. It will be assuredly a further advantage if the work does not call for the use of elaborate or expensive apparatus and is adapted to the season when the classes are formed. And finally it is essential that the results may be of nearly equal value to those who go no farther than the first year or term and to those who use this as a basis for subsequent studies. Such an introduction to the more purely physical sciences is a desideratum that need not be discussed here where the object is merely to suggest a beginning in the study of organic nature, which, though by means ideal, is the writer's approximation to these principles and which has justified itself in practical use.

Our subject matter is the silva of our neighborhood; and our first work is the identification and naming of all available species of native trees and shrubs. This is perhaps the most distinctive feature of our course, and may require some explanation regarding the method pursued. As a result of some years of tentative efforts we have now in use a key, or index, based on the leaf-

characters and combining these in such a way as to make tolerably certain and surprisingly easy the determination of any given species. The necessary knowledge of leaf-forms, with the terms needed, can be readily mastered in from five to ten lessons, and the learner of two weeks' standing is in a position to practice methodical observation and conclusion without assistance, as effectively within his limits as could be possible with the usual "Flora" after the preparation of a full term. Having thus rendered the pupils largely independent of his assistance, the teacher is now free to extend the work in various directions, and, while identification remains the center of interest, it is supplemented by a careful description and drawing, and reference to such facts as are of interest in connection with forest botany. As soon as a sufficient number of forms have been examined, attention is directed to comparative features in illustration of the principles of natural classification, which will not be fully appreciated until the floral organs are studied in the succeeding spring. In this way we emphasize the distinction between identification and classification, which are often strangely confused nowadays. At this stage we require for each species studied, as far as possible, an accurate drawing of the leaf, with tabular description, a note on the economic or other uses and a quotation from some standard author, containing an appropriate allusion. Now, too, a beginning is made along the more usual lines in the study of flowers and fruits in anticipation of the resumption of floral botany in its season, which is surely the spring and early summer.

Having thus occupied short daily lessons throughout September and early October, we turn our attention to another phase of the subject. Our school grounds are quite extensive, and when first occupied, some few years ago, were altogether devoid of trees and shrubbery, so that the question of planting became of immediate interest. Since then we have continued this work in spring and autumn in connection with our classes with gratifying results, and the specimens brought from neighboring woods, for ornamental purposes at first, have increased in number and variety until nearly all our native species are represented. Although such a plantation, limited as it must be by the character of the soil and the circumstances of its formation, will show little of scientific

arrangement, its value for reference and study is scarcely lessened by this fact, and we hope that in a few years our arboretum will prove an asset comparable in value with a library or an equipment of scientific apparatus.

Along these lines we have sought to introduce in autumn classes the practical study of botany, and, judging from experience, the method is worthy of the serious consideration of teachers. The discussion of the features involved must from want of space be left to our readers, but we would especially call attention to the fact that the work blends naturally with the youthful interest in trees and leads to a firmer and more intelligent interest in the problems of forestry, which are beginning to occupy so much attention. These considerations are surely of some moment in a country where it has been said that the chief occupation of the people is the destruction of trees and, if for no other reason, might well justify an autumn course of a few weeks in Forest Botany.

THE PRESENTATION OF PHYSIOLOGY TO HIGH SCHOOL CLASSES.

BY WINFIELD S. HALL.

Professor of Physiology, Northwestern University Medical School, Chicago.

The object of this article is not to demonstrate that physiology should form a part of the high school curriculum, that being universally conceded, but to suggest a method of presenting physiology which shall be in harmony with advanced pedagogy.

The suggestions embodied in this article are the outgrowth of over ten years of experience in teaching the biological sciences, including physiology, in the secondary school, the college and the university.

The thoughtful teacher can hardly meet, in the biological or the physiological laboratory, pupils ranging in age from 15 to 45 years without becoming convinced of the fact that the method best adapted to one extreme is at the same time best adapted to the other extreme and to all intermediate ages. There would, there-

fore, seem to be fundamental principles underlying the presentation of the biological sciences. It is to the discussion of these principles of pedagogy and their application that this article is to be devoted.

Man is a child of nature and instinctively recognizes the unity of nature. To present physiology as "Human Physiology"—as a subject which stands separate and apart from all other branches of the curriculum—is a fatal error which is certain to result in meager success, if not in complete failure. Pupils rarely become interested in human physiology, as such. They get tired of the study of isolated facts about bones, muscles, stomachs and brains. By the time pupils have reached the high school they are thrilled by the vague questionings and wonderings incident to adolescent development. It is the period of "storm and stress." The youth is asking whence he came and whither he is going. He is observing nature, and, recognizing the unity of living nature, asks whence it came and what is his relation to it all. In presenting physiology to these pupils, any method which does not take into account the above facts must be defective and unsuccessful.

Physiology is one of the biological sciences. It deals with the action or function of structures described in morphology. It is not only a legitimate part, it is an essential part, of all biological teaching. One does as much violence to the youth's inherent idea of the fitness of things by describing the structures of a flower without reference to its function and its significance in the realm of nature, as one would do by describing wheels without allowing the youth to see them "go round."

Morphology is the study of dead and inactive organs; physiology is the study of the life and activity of organs. At this particular age the youth abhors death and turns instinctively toward life.

The principle above discussed applies, of course, to a particular age, viz., the early adolescent age. It has been intimated that one general method is applicable to all ages. Reference was made to *the laboratory method* now universally adopted for the biological sciences, though its adoption in physiology is so recent that some may think the method still open to question. To any such the writer brings assurance that any other method than the exper-

imental one is as much out of place in physiology as it would be in physics, chemistry or biology. When presented as an experimental science, and by the inductive method in the laboratory, physiology becomes at once one of the most important of all the natural sciences as a means of education.

With all these facts and principles before us, how shall we present physiology to the high school class? Before this question can be answered it will be necessary to find out how much the members of the class already know of biology. If they have had the advantage of the best education, they are familiar, through a systematic course of nature study extending over the eight years preceding the high-school course, with the more prominent features of the morphology of plants and animals. They know that the domestic animals have backbones and that this structure marks them as more or less closely related to man. They are able to point to the parts of the horse, cow, dog or cat that correspond to the shoulder, elbow, wrist, finger, hip, knee, ankle or toe of man. They are familiar with the habits of all the domestic and many of the wild mammals and birds. They are familiar with the habits and with certain general features of the more common insects in their imago and larval forms. They know the common names of the familiar trees, flowers, ferns and grasses, and know something of the conditions under which they thrive. They know some of the general features of the anatomy of man and of the processes which go on in the human body. Their teachers have shown, *in vitro*, digestive and other physiological processes, and they know something of the significance of foods and the offices which they serve in the body. Finally, they have been well drilled in the most important rules of hygiene, both personal and domestic. All this they should know before they enter the high school.

In the high school the pupil receives for the first time instruction in nature sufficiently systematic to be dignified by the name of *Biology*. In the first year he should have a thorough course in elementary botany. It should be a laboratory course supplemented by recitations. The plants studied should be few in number and the technicalities of a detailed morphology should not be attempted. What the student at this age needs is a knowledge of the life histories of plants and animals. How do they live? How do

they reproduce their kind? What becomes of them when they die? Why do two plants of the same species differ, one from the other? How do these living forms come to be? Are they changing? If so, why? In the high-school course in botany, physiology should be made more prominent than morphology.

In the second year of the high school there should be a course in zoölogy planned, like the botany, to emphasize the life histories, and to answer for animals, questions similar to those raised in the study of plants. All of this in preparation for the study of high-school physiology.

With a preparation for physiology so thorough as that outlined above, I should make this branch rather the *biology of man* than simple human physiology. Let the class study the animal—*Homo;* his species, varieties and races; the geographical distribution of the races and their characteristics. Let them review the morphology of man in its general features, and institute comparisons between man and his nearest associates among the vertebrates. The student may perform for himself many experiments which will reveal the general characteristics of foods and foodstuffs, and the general steps of digestion.

There are many simple experiments which illustrate the principles involved in circulation, respiration, vision, hearing, etc., that can be profitably introduced as part of the laboratory course. The observations, notes and conclusions of the laboratory make the basis of the knowledge which the teacher can systematize in the recitation room.

Questions of life history, reproduction, whence, how and whither would better not be discussed. The courses in botany and zoölogy have sharpened the senses and incited the thoughtful questioning of the pupil. When he comes to the study of man, leave him alone with his thoughts on these deeper and more delicate questions, and he will arrive at the Truth.

THE TEACHING OF PHYSICAL GEOGRAPHY

BY WM. H. SNYDER.

Master in Science, Worcester (Mass.) Academy.

(*Concluded from page 25.*)

The hills are the place of pasturage, and woodland, the place for wild animals and flowers. Here the roads are winding and the houses few. The saw-mills and the small manufactories appear in the side valleys. This is all characteristic of mountain regions. In valleys are fertile farms, large manufactories, railways, the bustle and hum of trade, large cities and a large part of the wealth of communities. So it is with the great valleys, like the Mississippi, the Rhine and the Volga. Ponds present many of the features of the ocean, but of course they do not show the tides, the steady currents or the large waves. The isolation of the hill town and the difficulty of traveling the hill road gives a pretty good idea of the difficulty of invading a mountainous country with an army—the reason why Austria with all her power could not hold Switzerland. Rivers which separate the dwellers on one side from those on the other by almost impassable barriers, so that people miles apart on the same side of the river are really nearer and have more relations with each other than those who are separated by the comparatively narrow channel of the river, illustrate to us how England, separated as she is from the Continent only by the narrow channel of Dover Straits, has been influenced so little by her Continental neighbors and has been able to remain independent of them and undisturbed by them for so many years. Some years ago while in Paris I had a chance to discuss with a general of the English army the proposed Dover Straits tunnel. He told me that the English officers were all opposed to this project, as a connection of this kind would tend to undermine England's vast advantage of isolation. If England's terminal could in any way be placed in the hands of the Continental troops for a short time only a vast army could be moved across to the island. Like Athens in days of old, England's wooden walls are her safeguard. Example after example of this kind, where the conditions of the home locality explain and illustrate conditions in far distant parts of the earth and throw light upon history and travel, might be cited if there were time.

Such is the kind of application meant by the humanistic side of the subject, and it is this as much as anything else which gives relish and interest. You will be surprised if you have not already considered the subject to find out how much of that which seems blind in history is explained by a knowledge of physical geography. A friend of mine a short time ago, from some studies he had made in geography, gave the most rational explanation ever made for one of Caesar's campaigns in the Gallic war. A right study of physical geography explains many problems, not only in history, but also in economics and politics. A man who has made a study of the geography of our country will have much more sympathy with its political differences than he who has not. He will appreciate that different positions make different conditions, and that different conditions make different conclusions. What is best for manufacturing New England may not be best for cattle-raising Texas. The different industries of these different sections are not due to the fact that the New Englander is born with the buzz of wheels and machinery in his ears and the Texan ushered into the light of day with the thunder-like roar of stampeded cattle. It is because New England has the water power and Texas the cattle-raising plains.

Did slavery ever get a strong foot-hold in a mountainous region? Was a democratic form of government ever indigenous to a flat country? Questions like these will usually cause a real limbering up of the gray matter which often lies dormant in the head of many a boy and cause him of himself to try to find out something. If the teacher of physical geography is to make the most of his opportunities he must go beyond the study of what the surface forms of the earth are and how these were produced, and trace out the effects these forms have had on man and his history. And not only on man, but on life in general. As forms which are somewhat alike in appearance differ greatly in construction and manner of formation and on account of these differences affect life very differently, he must study how these forms came to be what they are. Here the great history of the earth begins to unfold before him, and although the vista may be too great for him to attempt to scan, yet the glory of the sight cannot fail to be an uplift both to him and to his pupils. The earth

and man! to what higher thoughts can man aspire except in the search for God himself!

Let us then concede that the teacher of physical geography must make a careful study of his subject and that in this study he will receive as great benefits as in any other study. What is the duty of the school toward this subject? The best work cannot be done without a suitable equipment. The school that desires satisfactory geographical teaching must provide its teacher with suitable maps, models, reference books, and pictures. It is impossible to give the pupil a clear conception of surface forms by the use of words only. An architect would not think of endeavoring to interest a client in his conception of a proposed building by simply talking to him about it. He has plans and specifications and sometimes even models made so that both the ear and the eye may aid the brain in forming a picture of the structure. If this is necessary in dealing with buildings of moderate dimensions and with mature men, is it not reasonable for the teacher to demand similar assistance in endeavoring to give the pupil a correct conception of the various forms and conditions of the earth's surface? No matter how well the teacher may use the home field for illustration, there will of necessity be many formations which have no similarity with the local forms. If these are to be at all appreciated, material must be furnished for illustration. The cost of supplying an adequate amount of this material is comparatively small. There is probably no branch of natural science which needs so little outlay for a suitable equipment. Pictures and maps are very cheap, and models are not very expensive. Maps illustrating the different portions of our own country and about all kinds of geographical forms can be purchased of the Government for two dollars a hundred. Foreign maps can be imported into the country for school purposes free of duty. Illustrated books which contain a large number of illustrations useful in teaching geography can be bought for a small sum. These illustrations can be cut out and mounted on cards so as to be handy for use. When all mounted they need not cost more than three or four cents apiece. For half what it costs to establish a decent course in physics or chemistry, a rather complete equipment can be obtained in physical geography. The

cost for maintenance is also less than that for either of these subjects. There are few schools of even moderate size which cannot afford an equipment which is adequate for a well developed course in this subject. It is the subject, too, in which, when properly equipped, the largest number of pupils can be interested, as it requires no mathematics and but little abstract thinking. If laboratory work is to be done, an ordinary class room can be used. Girls can do the laboratory work as well as boys. The benefit of this kind of work to the average boy and girl cannot fail to be as great as that of any of the other laboratory courses. In schools where room and means are wanting it is the only course which can be readily made to employ the hand as well as the brain.

Another question which is important to us in the consideration of this subject is that of time, both the point in the course where physical geography can best be placed and the number of hours best to allot to it. Here as elsewhere what is best for one school, is not necessarily best for all. The general principle might be laid down, however, that the later it can come in the course without detriment to subjects which must necessarily be taken late on account of college requirements, the better it will be. In the Worcester Academy it is placed in the second year. For us this is the best place. It follows botany and zoölogy and precedes physics and chemistry. There are many reasons why physics would better come first, but if physics is to be made a mathematical subject it is almost necessary to have it follow algebra and geometry, and to do this it cannot come earlier than the junior year. The laboratory work in physical geography is also a very good introduction for that in physics. For a school which is preparing for college and scientific schools, there are several reasons that would naturally place it not later than this point. It should not be placed earlier if it is to be made anything more than a general informational course. The quality of the reasoning demanded from the student will require the maturity of at least one year of high school training. As to school time given to this study it should at least be one year of four periods per week. More time can be used to advantage and any less will render the course scrappy. If the subject is worth teaching at all it is worth doing

well, and it cannot be done well unless sufficient time is given given for a somewhat systematic presentation. A boy must be taught to think, to see and to do in geography. There must be time for the geographical concepts to snugly nestle themselves among the brain cells of his mind and lose the feeling of strangeness and bewilderment. It takes time for the mind to associate ideas with facts and names. The whole material of geography as a science is new to the boy, and it must have time to soak in. The average boy is not a boa constrictor, the cram method to the contrary, and he is not obliged to swallow and digest everything that is shoved into his mouth. If too much material is put in, or put in too fast, he generally gets but little nourishment out of it. Line upon line, precept upon precept, here a little and there a little, is what he needs to make a subject really of value to him. Geography is a worthy subject, he can spend a year on it to advantage, it will not sour on his stomach, therefore if it is once begun, do not change the diet. Throw in a little more meteorology and geology if necessary, as they are similar in digestivity, and may add a little variety and spice.

If physical geography is to have its fullest usefulness in the school course, the work should be divided into three divisions, the class room, the laboratory, and the field. In the class room it should be seen that the pupil every day prepared for recitation a certain number of pages from some trustworthy text-book. If the book is a good one much benefit must accrue from familiarity with its contents. The pupil should learn to teach himself from a book and not think that all his teaching must come from the teacher. Good books are useful things and he ought to become able to use them. To be able to rightly use books he must at first be made to use them. It is necessary that physical geography as well as his other subjects should teach him to study, and study regularly. In the class room also let the text-book be explained and discussed, the laboratory and field work talked over and straightened out. All the acquired information of the teacher should here be used to give the student a clear and well rounded understanding of the subject. The quiz, the lecture and the topic method should be brought into use and the masticating and digesting of the subject accomplished. If there is anything

that is not clear, let it be here explained, if there is anything that the boy knows which it will help the class to know, let it be here pulled out. All geographical phenomena which have been observed by either teacher or class should be here exploited. The room should be used both as an injector and an extractor. A red hot poker with WHY on the end of it should be kept handy for a branding iron and before the year is out it should have been used sufficiently often to make an ineradicable impression. The boy should be made to utilize the knowledge he has already acquired in explaining new phenomena. He should here acquire that delightful sensation, so hard to impart, that he himself is really expected to do some work and even sometimes to think.

The laboratory in physical geography should be the explainer, the illustrator, and the enlarger. Here should be studied the methods of representing geographical forms and when the methods are understood, the forms themselves, as thus represented. This is the place where the boy should become accustomed to the use of geographical tools. He should learn what are the advantages and what are the defects of the different methods of earth portrayal and how to interpret the meaning of different kinds of representations. Here he can study in outline those earth features which he is unable to see in reality. From the representations of many different forms he will get a broadened view. He will learn to appreciate the conditions of distant sections by use of the ordinary methods of representation and thus be able to find out by himself at home what many men have to travel great distances to learn.

In the field excursions the phenomena of the home locality should be carefully observed. All geographical activities and forms which manifest themselves in the neighborhood of the school should be studied. This work should as far as possible be made a basis for the rest of the work of the course. Every thing possible should be referred for comparison to something in the home field. The comparison will often be of assistance even if rather far fetched. The known renders the unknown knowable. The average boy or girl is a pretty good expander if he has a little something to start from. Thus the home field if properly handled will illustrate many phenomena which it

does not itself exhibit. It must be indeed the foundation for all farther study. Not simply "Know thyself," but know thy home field, should be the motto of the teacher of physical geography. The aim of the student of physical geography then should be to see and to understand the features and activities of the earth which are about him, to be able from his knowledge of the conditions which he can see to explain conditions which he cannot see, to examine into the causes which have shaped the earth's surface and to try to understand the effects that different earth formations have upon man. From his knowledge of Nature's forces and their products to get a larger and nobler view of the world and his relations to it. To see that the continual and persistent action of unobtrusive and apparently insignificant forces have produced the grand features which inspire him with wonder and awe and thus to realize that the small and unobserved acts of his own life will form a part of those great movements which are shaping the destiny of mankind.

ZOÖLOGY IN SECONDARY SCHOOLS.*

BY MAURICE A. BIGELOW.

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The various aims which have been suggested by authors on elementary zoölogy may, in the opinion of the writer, be conveniently classified into two groups. In the first group may be classed all aims which have a direct reference to scientific training; while in the second may be included all aims relating to the acquirement of knowledge of the subject matter.

The aims in the first group, stated in a general way, have reference to the development of a scientific attitude of mind, by directing various mental processes, such as scientific observing, reasoning on the basis of demonstrated facts, exercising judgment and discrimination, and learning to appreciate demonstrated knowledge. This is not the place to attempt a complete analysis

*This paper contains the essentials of the preface to an outline of a course in zoölogy, which, together with an outline and discussion of a course in botany by F. E. Lloyd, appeared in the *Teachers' College Record*, Vol. II, No. I, Jan., 1901, published by the Columbia University Press.

of the attitude of mind which characterizes the student of science. Enough has been said to indicate the general direction of the first group of aims. The importance of the training which this involves has long been recognized, and the discussion need not be renewed here.

It is evident in the form of the statement that the aims of the first group are not advocated as peculiar to zoölogy. It is now well recognized that all of the sciences furnish materials for developing the chief elements of the general scientific attitude of mind. The writer accepts the opinion of many teachers that in the teaching of every science in a secondary school it should be borne in mind that, since few pupils have opportunities for the thorough study of several sciences, no occasion should be neglected for giving training in scientific observing and scientific thinking. Many educators regard such training as far more important in liberal education than the knowledge of the facts of any science. However, it is not necessary in teaching a science with scientific training as one leading aim that its essential facts should be neglected, for the training depends largely upon the method of teaching rather than upon the subject matter. The realization of these aims is found in the general method of modern science—the laboratory method; but the quality of the training depends upon the way in which the laboratory work is directed. If the aims of the first group are to meet with the greatest possible realization, it is necessary that they be kept in mind while planning a laboratory course in zoölogy, for very much depends upon the manner in which problems for solution are presented to the minds of the pupils.

Aside from the training in mental processes which the study of zoölogy may give the pupil, there is an important phase in which zoölogy stands upon its own merits as a science with subject matter, some knowledge of which is believed to form a valuable part of liberal education. The second group of aims—second only in order of statement—is concerned with the acquirement of important facts and ideas of zoölogy.

In selecting the subject matter for an elementary course in zoölogy for secondary schools, the field of zoölogical knowledge should be viewed from the standpoint of liberal education, as

distinguished from special or technical education. The field is wide, and at best only a glimpse of animal structure and life can be given in a single course. Bearing in mind that the great majority of secondary pupils can never follow more than one course of instruction in the subject, the problem is to fill that one course with those zoölogical facts and ideas which have the closest relation to the everyday life of a liberally educated man. In the future it should be recognized more clearly than in the past that many phases of the science of zoölogy, which are of interest and importance to the specialist, may have no definite meaning to a man in other walks of life. Many teachers of zoölogy in secondary schools do not seem to have examined the subject in this light, and as a result elementary zoölogy has been too often taught as if it were the aim to train the pupils for professional work in zoölogy or in some of its direct applications, such as medicine. This special or technical training is the proper work of colleges, and has no more place in the secondary school than have higher applied mathematics.

The wide difference between the aims which govern the zoölogical teaching in colleges and those which should underlie the work in the secondary schools needs to be emphasized, for already there have been too many attempts to transfer college courses and books into the secondary school. It is not a question of how near an approach can be made to the college introductory course in zoölogy, but a question of the value of such work in liberal secondary education. Is it the most valuable which can be selected from the wide field of zoölogy? This is the really vital question which apparently has been asked by few of those who have prepared outlines of study for elementary zoölogy in secondary schools.

The course in elementary zoölogy which in the past decade has been followed in the majority of schools consists largely of detailed comparative study of the anatomy of a series of animals. It is a very close imitation of a common introductory course for college students. Several published books well represent this morphological course, and one who examines carefully is forced to conclude that very much of the subject matter is so technical and detailed as to be of very doubtful value to a liberally educated

man who has no special reason for being learned in zoölogical science. In such a course there is no time for the pupil to learn anything about the life of animals or even the existence of many important animals, and, as usually conducted with preserved specimens, it is far from being a study of animal life. It is evident that the course under discussion will give pupils who follow it an extremely narrow view of the animal kingdom in its varied aspects.

The introductory college course in zoölogy from the morphological standpoint is usually followed by other courses in which other phases of zoölogy are considered, and in the end the students may gain a broad view of the field of zoölogy, and learn to think of animals in the various aspects of their structural and functional relations. In the college system the student is expected to acquire much technical information while he is getting a general view of the field of zoölogy. In the secondary school the technical matter is undesirable, but the general view is of great importance, and in one short course within a single year (usually a half-year) must be included all that the majority of pupils are ever to be taught about animals. Are we not justified in concluding that an isolated course from the standpoint of comparative anatomy, while perhaps well adapted to the college system, fails to give the wide view of animals which is desirable in liberal education, and, therefore, does not meet the needs of the majority of secondary pupils?

It is now sometimes urged in defense of the course in anatomy that the working out of details of structure tends to give valuable scientific training. But much of this is purely special training, and the facts of detail are only of technical value. There is a growing belief among naturalists that much of the anatomical study in secondary courses can be replaced with more important subject matter, and this with no loss so far as efficiency in developing scientific observing and thinking is concerned.

In so far as it deals with the great facts of animal structure, the anatomical course has many good features which commend it for secondary education; but in so far as stress is placed upon details and comparisons of number, minute structure, exact extent and position of organs in some half dozen types of animals, the

study must be regarded not only as of little importance in liberal secondary education, but also as using time which should be devoted to undoubtedly more important phases of zoölogical study. But since the study of general anatomical structure is important as giving a basis for other phases of zoölogical study, therefore it is necessary that this much of the morphological course should be retained.

Within recent years there has been a reaction and a decided tendency toward abandoning many of the characteristic features of the morphological course, and returning toward the old-time natural history course. Such a course, as usually presented, has little or nothing to do with the study of internal structures of animals, and consequently there can be no scientific consideration of the fundamental physiological processes. Emphasis is placed on study of external form, classification, movements, habitats and life histories of animals. Such studies of animal life and its relations are especially valuable in preparation for college courses which are largely composed of those phases of zoölogy which have little concern with natural history.

(*To be continued.*)

ELEMENTARY CHEMISTRY IN THE HIGH SCHOOL.

BY ALBERT S. PERKINS,

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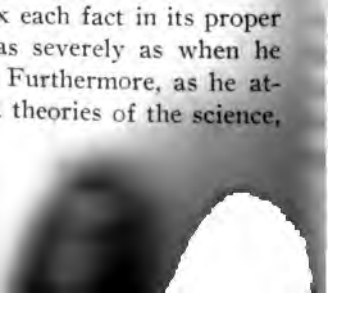
Perhaps no department of knowledge, when considered upon its informational and its disciplinary side, deserves a higher place in the work of the secondary school, of the college, and of the graduate school than chemistry. For what knowledge is more important or interesting than that which deals with the constitution of things and the laws which govern the unceasing changes in matter? On the other hand, a student of chemistry, as he tries to master the great mass of detail, and to fix each fact in its proper relation, finds his memory taxed quite as severely as when he wrestles with Greek forms and syntax. Furthermore, as he attempts to comprehend the hypotheses and theories of the science,



he learns, perhaps for the first time, something about the importance and power of imagination. Moreover, at every stage of progress, our student finds his reason leading him through the maze of unsound hypotheses and error to truth, the distant goal. Surely no other study is better fitted to train the mind to think—the true end of education.

Chemistry as a science is young. In our American colleges previous to the Revolution, it was an obscure and unimportant part of Natural Philosophy. Moreover, Natural Philosophy itself, at this early day, was crude and unscientific, and bore little resemblance to modern physics.

It was in the medical schools of the country, in connection with Materia Medica, that the science first took root. Thus we find chemistry taught by itself in the medical school of the University of Pennsylvania in 1768, in the Harvard Medical in 1782, and at Dartmouth in 1798.

Princeton was the first academic college to award to chemistry the dignity of a separate chair, and in 1795 Dr. John Maclean became the first professor of chemistry in an American college.

From 1800 to 1845 the growth of scientific studies in the United States was slow. During this period chemistry continued to be taught as a part of a medical education, and in the colleges in a half-hearted, unscientific way as information. Strangely enough, during those years in which Davy and Faraday delivered their lectures before the Royal Institution, and Liebig and Wöhler were conducting their historic researches, chemistry was taught in the United States as a mere "bread and butter" study, with no recognition of the value of original investigation as an educational instrument, and with no conception of the importance of individual laboratory work by the pupil. Fortunately for our country, during the latter part of this period the large number of American students at the great German universities caught the spirit of scientific research. The result was not the broadening of the college curriculum by the addition of scientific studies, as we might have expected, but the formation of separate scientific schools, which for decades were looked upon as inferior to the older institutions.

In these schools pupils began to perform laboratory work,

and, in a crude way, it is true, to reason along scientific lines. About 1860 the value of scientific studies began to be recognized in the academic colleges, and the last forty years have recorded the continuous advance of scientific methods in all our higher institutions, until today the scientific spirit dominates the teaching even of the old humanities themselves.

During this period of scientific growth the high school has been incorporated into our public school system. Leaving the preparation for college to the older academies, the public school at first was intended only for those pupils not expecting to go higher. Thus emphasis was laid upon mathematical and scientific branches, rather than upon the so-called classical studies.

While occasionally a high-school graduate entered a scientific school, and later, largely through the grace of the teacher, a few others entered college, it was not until the colleges, only a few years ago, recognized the so-called English studies as equal to Greek and Latin in disciplinary power, that the high schools became their chief feeders. From the start chemistry has been an important study in the high-school curriculum. In the early years the teaching may have been crude and unscientific, from the modern standpoint, with very little laboratory work and with a great deal of memory work from the text-book, but always with full recognition of the importance of the science as a part of a liberal education. As time went on laboratory work in chemistry became more and more common. Gradually, as new buildings were erected, the chemical laboratory was given a place, and in the latter seventies and early eighties we find pupils in schools still laying too great emphasis upon memory work, perhaps, but also performing illustrative experiments in descriptive chemistry, and recording their results. In some of the larger city high schools there was also an advanced chemistry class, which often did comprehensive and accurate work in qualitative analysis. So thorough was the work in these two courses at this time that we are not surprised to find the Boston Superintendent of Schools in one of his annual reports referring to it as fully up to the standard of the smaller colleges.

The year 1888 marks an era in the history of secondary school chemistry.

Harvard in its recent change in the requirements for admission had placed laboratory chemistry on a par with advanced Latin and advanced Greek, and "Laboratory Practice," by Prof. Cooke, was published, to indicate the kind of work which would be acceptable to the college authorities.

Informational work of the Eliot and Storer or Shepard type, which up to this time had prevailed in the high school, was placed under the ban, and quantitative experiments, many of them long and difficult, leading up to the theories and laws of the whole field of chemistry, were substituted.

Unfortunately, the book was not the result of experience, so that the first attempts to follow it in the high school were attended with much difficulty.

Moreover, many of the high school teachers of chemistry had not studied beyond qualitative analysis themselves, and consequently did not understand the book. Besides, few of the experiments could be performed in the time allotted to the laboratory work, and if attempts were made to lengthen the period, the high-school programme, always difficult to arrange satisfactorily, was upset. Then finally, if the teacher had been thoroughly educated in chemistry, and understood how to translate the spirit of the book to the pupils, so that they could perform the experiments intelligently; and if he had succeeded in getting in his double periods for laboratory work without too serious a disturbance of the programme, and without exciting alarm among his fellow-teachers; if, I say, a high-school teacher of chemistry had succeeded in doing all this, thus giving Cooke's "Laboratory Practice" a fair trial, the result appeared to be a dismal failure. For the pupils did not "get anywhere;" they did not "know any chemistry," as it was said. And I think that most high-school teachers will agree that no study, however disciplinary it may be, deserves a place in the high-school course of study which does not leave some valuable information with the pupil.

Twelve years have done much to smooth down the ruffled feelings caused by this book. Most chemistry teachers today are agreed that there should be not a little descriptive work of the Eliot and Storer type, to enable the pupil to understand what the laws and hypotheses are all about. Moreover, in order that a true

conception, and not what Herbert Spencer calls a symbolic conception, of the theoretical side may be gained, there should be quantitative experiments; and most important of all, the teacher should be thoroughly educated in the science, so that the research spirit should pervade the whole course. Fortunately, secondary teachers in chemistry have been met in a cordial spirit by the colleges, and we have today as types of what our work should be from the college standpoint, such excellent books as Dr. Torrey's "Studies in Chemistry" and Prof. Richards' "Pamphlet," as it is familiarly called.

The extraordinary growth in secondary education during the last twenty-five years affords to us a faint conception of the dignity to which the twentieth century high school is sure to attain. Is it too much to expect that another quarter of a century will find our public high school brought up to the standard of the German gymnasium, perhaps displacing the college, which in the opinion of many has no logical place in an educational system?

With the extension of the elective system in the secondary school, which is sure to come, the addition of two years to the course would be a natural result, thus bringing the pupil to what at present is the beginning of the junior year in college. Thus a high-school graduate would be well prepared to begin his professional course, or if he chose to pursue his academic studies higher, during the junior and senior college years he could do the work now relegated to the graduate school.

Let us hope that throughout the whole of the twentieth century, in a matter which concerns to such a degree the common welfare, merit shall be recognized and political influence shall disappear.

In such a school, chemistry, from its very nature, will occupy a prominent place, and will be emphasized upon its educational rather than its informational side. The pupils, young men and young women, will perform, in a well equipped laboratory, experiments, partly quantitative and partly qualitative, covering the whole field of the science. The teacher, a broad-minded man or woman, very likely a doctor of philosophy, by individual instruction in the laboratory, by "quizzes" and by lectures, will lead the class from one step to another, stopping not even at the law of

mass action, nor—dare I say it?—at phase relations—the research spirit pervading every part of the work.

Once or twice a year, perhaps, in presenting a subject, the teacher will draw his material from the original papers themselves. The pupils will at every stage of progress instinctively feel that chemistry is not a dead mass of laws and formulæ and equations, but a science, fairly throbbing with life, whose marvelous growth has been due to just those lines of thought which they, themselves, have been pursuing.

DEVICES USEFUL FOR DEMONSTRATION PURPOSES.*

BY E. L. NICHOLS.

Professor of Physics, Cornell University.

I have often urged at these meetings the desirability of devoting a portion of our time to the consideration of practical physics, and it is for that reason, perhaps, that I have been asked to set the example today.

The devices to be described are not altogether new, and they are of a very simple nature. For their simplicity I have no apology to offer, it being a first principle of experimental demonstration that the apparatus should be shorn of every unnecessary feature which might distract the mind from the contemplation of the phenomenon to be exhibited or bewilder the student in his attempt to grasp the principle to be illustrated.

I.

An apparatus for showing in a semi-quantitative way the expansion of air at constant pressure.

In exhibiting the phenomenon of the expansion of gases by heat it is desirable to afford the most direct possible ocular demonstration, not only that expansion occurs, but likewise to show approximately how great that expansion is. The ordinary form of air thermometer fails in the latter respect, because we are un-

*Abstract of a paper read before the State Science Teachers' Association, Rochester, Dec. 28, 1900.

able to estimate even approximately by inspection the relation of the total content, including bulb and neck, to the volume of the mercury displaced in the process of expansion. In a cylindrical vessel the volume is, however, directly proportional to the length of the cylinder and the change of the volume between the ice point and the steam point ($\frac{1}{3\frac{6}{7}\frac{6}{3}}$ of the volume at zero) is so great that it can be estimated with the unaided eye. In the apparatus which I have adopted for the purpose after trying a variety of forms, the very ingenious and simple device employed in the usual experiment for demonstrating Boyle's law is used. A tube 100 cm. long and about 5 cm. in diameter is closed at the lower end and two-thirds filled with mercury. (See Fig. 1.)

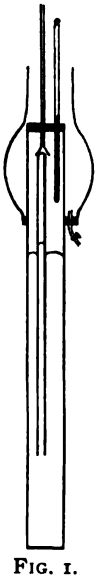


FIG. 1.

A small tube, likewise closed at one end, and graduated in cubic centimeters from the bottom upward, is inverted in this mercury cistern as in the usual Mariotte apparatus. It is convenient to select for this purpose a tube the total contents of which are 100 cubic centimeters. Such tubes already graduated may be purchased of any dealer in chemical apparatus. If the amount of air entrapped in the upper end of this inner tube be such that, when the tube is pushed down so that the height of the inner column of mercury is at the level of mercury in the outer cistern, its volume is 27.3 cc. At zero, the apparatus becomes direct reading. To adjust the pressure of the enclosed gas to exactly one atmosphere, a rubber cork is fitted to the open mouth of the larger tube. Through a hole in this cork a tube slides with sufficient friction to hold it in position at whatever point it may be released. The lower end of this sliding tube is enlarged in the blowpipe flame into the form of a small inverted cup. Within the hollow of this little cup the top of the tube, which floats in the mercury, is placed. The floating tube will then stand vertically in the center of the cistern and its height can be adjusted with ease so that, whatever may be the temperature, the mercury columns inside and outside of the tube will co-

incide. I know of no more simple or satisfactory method of maintaining the enclosed gas at a constant pressure of one atmosphere. To bring the enclosed volume of air to the temperatures of zero C. and 100 degrees C. an ordinary lamp chimney of the largest size is mounted so as to surround the entire upper portion of the outer tube as shown in Fig 1. The space between this lamp chimney and the outer tube may then be filled with water and crushed ice, or a jet of steam may be introduced to bring the enclosed parts to a higher temperature.

In using the apparatus for class room or lecture demonstration it is well to start at the steam point. The apparatus having been previously set up and steam introduced for some little time before the beginning of the hour, the inner tube will have already attained the proper temperature when attention is first called to the subject. The inner tube is raised so that all may see the mercury column above the level in the mercury in the outer cistern. It is then lowered by pushing down the sliding tube until the pressure is exactly one atmosphere and the height of the column is read upon the graduated scale. The steam jet is now removed and the space between the outer tube and the chimney is filled with ice water. The mercury column within the inverted tube will soon be seen to begin to rise above the outer level. The apparatus is left standing while other topics to be presented to the class are considered, and just before the end of the period the final adjustment is undertaken. The diminution of volume due to fall of temperature having been pointed out, the sliding tube is then pushed down until the pressure is restored to normal, when the reading upon the graduated scale is again made. For the purpose of drawing off the condensed steam, and likewise the water from the bath, it is convenient to insert through the collar upon which the glass chimney is mounted a small tube with stop-cock, as shown in the figure. A siphon may, however, be employed for this purpose. Another convenient addition to the apparatus is a thermometer inserted through a hole in the upper cork, by means of which one can ascertain when the change of temperature is completed. Successful working of this apparatus depends, of course, upon the uses of dry mercury and a perfectly dry inner tube. To secure the very best results the graduated tube should

be completely filled with mercury before inverting in the cistern and air dried by passing through strong sulphuric acid or through drying tubes with potassium oxide or phosphorous pentoxide should be introduced by means of an inverted siphon. If these precautions be taken the apparatus will serve very well for quantitative laboratory work on the coefficient of expansion of air, although of course it is not possible to make readings to the degree of exactitude that may be obtained with more refined apparatus.

II.

Floats adjusted to show the phenomenon of the maximum density of water.

The fact that water reaches its maximum density at 4 degrees C. is of course touched upon even in our most elementary courses of experimental physics, and various forms of apparatus have

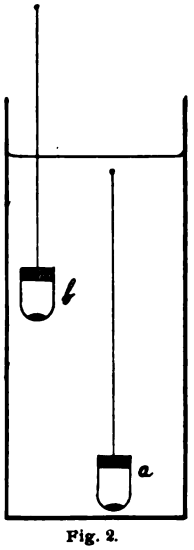


Fig. 2.

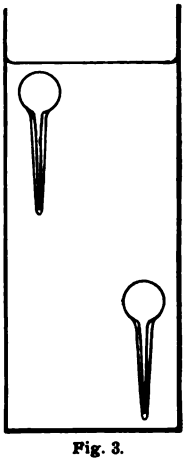


Fig. 3.

been suggested for the purpose of showing this phenomenon. The simplest of these consists of a float, like that suggested by Preston in his well-known work on the Theory of Heat (p. 177), so adjusted that it will float in water at 4 degrees and sink in water

at zero. Such floats may be given various forms, one of which is shown in Fig. 2-*a*. This consists of a short piece of light glass tubing, preferably the bottom of an ordinary test tube, to which a cork is fitted. This cork should be of such size that it can be pushed down into the tube by slight pressure. The first approximate adjustment is made by pouring mercury into the tube until it will float nearly submerged in water with the cork inserted. A long, thin stem consisting of a fiber of glass not more than one-half a millimeter in diameter is now inserted vertically through the center of the cork and the tube is sealed by the application of a layer of cement (bicycle tire cement or ordinary sealing wax). Upon placing the float thus prepared in water at 10 degrees it will be found either too heavily or too lightly loaded. In the latter case further adjustment is possible by pushing the cork more deeply into the tube, thus decreasing its displacement, until it will sink. The final adjustment, which consists in lightening the tube as far as is possible without actually enabling it to float is performed by melting the tip of the glass fiber in a Bunsen flame and removing small portions of the melted glass. If too much is removed a still smaller amount may be restored in a similar manner. If this float be adjusted so that it will sink very slowly in water at 10 degrees it will do the same at zero because the density of water at these two temperatures is almost identical. It only remains to determine whether the adjustment is close enough to admit of its rising at the intermediate temperature of 4 degrees. When we consider how small the change of density is between these two temperatures, a unit of volume of water at zero diminishing to 0.99988 at 4 degrees and increasing again to 1.000125 at 10 degrees, it would seem at first hopeless to attempt to make such an adjustment. A little practice will show, however, that by successive alternate additions to and curtailment of the length of the glass fiber, the float may be brought to fulfill these delicate requirements. It will stand at the bottom of a cylinder of ice cold water, will rise slowly as the temperature approaches 4 degrees, and if care be taken to see that it is not permanently retained at the surface by the action of the surface film, it will sink again before 10 degrees has been reached.

Another plan likewise easily carried out consists in so adjust-

ing this simple instrument that it will float with a portion of the slender stem projecting through the surface volume at 10 degrees (Fig. 2-*b*). In this form the instrument becomes an extremely sensitive hydrometer of variable immersion, and its upward and downward movement between zero and 4 degrees and between 4 and 10 degrees will frequently amount to two or three centimeters. In this form the apparatus lends itself to the actual measurements of the change of density of the liquid.

To both of these forms the following objections may be urged: In the first place, they are exceedingly fragile, and in the second place, one never feels sure that the closing of the tube by means of the cemented cork is complete. The slightest leakage or the soaking of water into the cork through a layer of cement would speedily destroy the delicate balance of the instrument. On this account a float entirely constructed of glass and containing no mercury is to be preferred. A piece of ordinary glass tubing having a bore of about two millimeters is sealed at one end and is blown into a bulb about six or eight millimeters in diameter. The tube is then drawn out in the flame of the blast lamp at a point about 5 cm. from the bulb and sealed off. (Fig. 3.) This closed tube is now placed in water at 10 degrees. If it floats, more glass is added at the closed end until it sinks, and successive adjustments are made by adding to or substracting from the amount of glass at the heavy end until it sinks very slowly indeed at that temperature. In order to save time it is best to make two of these floats, adjusting the one in the flame while the other is cooling. It is not a long nor particularly difficult operation to adjust such floats, and they have the advantage of being permanent. After adjustment they may be placed in a bottle and will serve for a lifetime. For the purpose of demonstration it is only necessary to place the bottle in a bath of crushed ice or melting snow long enough to bring the contents into the neighborhood of the ice point and then to place the bottle upon the lecture table and allow it to warm up gradually in the atmosphere of the classroom. The bulbs which at the beginning of the experiment are at the bottom of the bottle will then rise and after the liquid has passed the temperature of 4 degrees will sink slowly again to their original position.

III.

The Torsion Balance Electrometer.

The Gold Leaf Electroscope is an instrument of such simple construction and of such delicacy that it answers the purpose of indicating the presence of static charges of electricity and likewise of determining their sign, in an admirable manner. There is, however, nothing quantitative about the action of such electroscopes in the ordinary form, and when we come to the question of measuring differences of electrical potential, the usual forms of electrometer are somewhat expensive to construct and difficult to handle. In the instrument now to be described I have endeavored to apply a principle already used by Threlfall for the measurement of the force of gravitation. Consider the case of a short rod mounted with freedom of rotation about the horizontal axis A B. (Fig. 4.) Its position of unstable equilibrium will be that in which the longer end of the rod is vertically above the axis of support. If now such a rod be fastened, at the point where the axis in the figure lies, to a horizontal fiber of quartz or to a fine wire, one end of which is fixed while the other is capable of be-

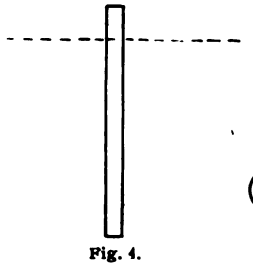


Fig. 4.

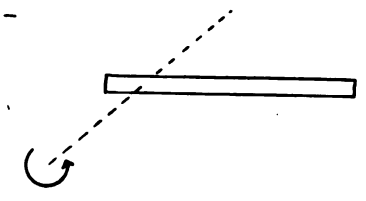


Fig. 5.

ing twisted by means of a micrometer screw, the twisting of the fiber will gradually lift the suspended bar with a motion of rotation out of its vertical position of stable equilibrium. The position of unstable equilibrium will no longer be vertical, but will make some angle with the vertical plane depending upon the stiffness of the fiber and the mass and adjustment of the rod. Finally, as the torque increases, the angle of instability is reached and the equilibrium of the rod is converted from the stable to the unstable type. As the position at which this change is approached the sensibility of the rod to forces tending to turn it upon its axis

increases indefinitely, so that by means of this device a torsion balance may be constructed, the sensitiveness of which, like that of the ordinary balance, may be increased at will up to the point where it is no longer possible to make it return to its zero position. By a suitable adjustment of the bar this position of maximum sensibility may be made to occur when the bar is in a horizontal plane (Fig. 5), and if the longer end of the bar be given a metallic coating and be charged, we have an instrument which may be used as an electroscope. By attaching to the short end of the bar a mirror, so that its angular movement can be carefully observed, and by using the micrometer screw at the torsion head to bring the bar back to its zero position, the instrument becomes an electrometer. The degree of sensitiveness to which an instrument of this type can be brought may be readily imagined. Threlfall found that with the form which he gave to it he could measure variations in the force of gravitation which did not amount to more than one part in a million. I am experimenting at present to see whether it were not possible to construct a manageable balance of this kind which will show the gravitational traction of bodies for one another. An apparatus which will do this, and which is easily handled in the classroom, would be, of course, a desirable addition to our equipment for demonstration. The principal fault which torsion balances of this type possess consists in the lack of sufficient damping. Whenever they are drawn out of the position of equilibrium they oscillate for a considerable time before coming to rest. Even if we are not able to overcome this fault, such balances will be useful in many ways. With them we may exhibit and compare magnetic attractions and repulsions by substituting for the charged body at the end of the rod a thin disk of iron. By placing vertically beneath this disk a coil of wire one may readily convert the apparatus into a sensitive ammeter.

In seeking to increase our means in illustrating the principles of physics, it is often better to endeavor to find new applications of existing apparatus, with such modifications as may be necessary, rather than to attempt to devise something entirely novel. This is the method of procedure which I have followed in the present paper, and the examples might be indefinitely extended. Take, for instance, the revolving mirror devised by Koe-

nig for the study of the manometric flame. This may be used in a large number of other striking experiments, by means of which the complex character of the electric spark may be shown, curves obtained from the composition of two vibrations either parallel or making any desired angle with one another may be exhibited, the periodical extinction of the alternating arc or the movements of such an arc in the magnetic field may be studied, etc. With another well-known and very simple instrument, the revolving disk with open sectors, innumerable fleeting phenomena may be exhibited. Prof. Boys, for example, used this device for showing the nature of the action of sound waves upon sensitive water jets. It is equally applicable to the observation of the changes of form of falling drops, the study of vibrating rods and strings or the mapping of the paths of projectiles. In all such work the aim should be to secure the greatest simplicity of construction compatible with the satisfactory operation of the instrument.

A CHEAP SUBSTITUTE FOR A PICNOMETER.

BY HUBERT G. SHAW.
Murdock School, Winchendon, Mass.

The adoption of the common forms of picnometers for class use in secondary schools is open to objection on two grounds—first, they are expensive, and second, the manipulation required is beyond the ability of the average pupil.

The substitute I suggest gives results accurate to the third decimal, is easy to clean and dry, is made in one piece (i. e. no stoppers to lose or break), and is cheap.

The specifications furnished to the dealer who made those in use in my school were: "One ounce flat-bottomed Florence flasks, with a ring around the neck, numbered consecutively." This is practically a small volumetric flask for self graduation. I have previously used graduated volumetric flasks. These may be obtained of twenty-five cubic centimeters capacity, but I think it is good for each pupil to calibrate his own. The numbering affords the easiest method of keeping a record of the (different) capacities of the flasks. The flasks cost fifteen cents apiece.

My pupils employ this apparatus for four experiments.

The first experiment is to find the capacity of the picnometer. The method is to weigh the picnometer empty, then filled to the mark with water. The difference of the weights in grams is taken to express the capacity of the flask in cubic centimeters. (In my classes the pupils have not at this time studied the expansion of water.) Later in the course we return to this calibration and repeat the work, allowing then both for the density of the water at the observed temperature, and also for the buoyant effect of the air.

The second experiment is to find the specific gravity of a liquid. The weight of the flask filled with the liquid is found. The weight of the empty flask and the weight of the water that fills it may be found again or may be taken from the preceding experiment.

The third experiment is to find the volume of one BB shot. "Count out one hundred (or any other known number) of BB shot into the picnometer. Weigh the picnometer plus the shot—fill to the mark with water and weigh again. Express your results in the following form:

Wt. of pn. + 100 BB shot	47.32 g.
Wt. of pn. + 100 BB shot + water	70.45
Wt. of water	23.13
Capacity of pn. No. 23 (see page 12?)	29.77 cc.
Volume of water	23.13
Volume of 100 BB shot	6.64
Volume of one BB shot	0.0664 cc. Ans.

The fourth experiment is to find the specific gravity of some solid by the picnometer. I generally employ small lead shot (because I have some in the laboratory for specific heat experiments).

And as my pupils have previously found the density of lead in grams per cubic centimeter by the graduated cylinder method, and the specific gravity by weighing in air and in water, the comparison of the results in the three cases affords evidence as to the relative accuracy of the methods.

I might add as one point in favor of these exercises that it gives practice in the exact reading of water levels, which helps in introducing the pupil to the use of the burette.

These flasks are easily cleaned and readily dried. I have a small table sixteen by twenty-seven inches and six inches high,

with holes three-fourths of an inch in diameter. The flasks are kept in this rack in the laboratory. The table thus serves not only as an excellent drying rack, but also as a safe place to prevent breaking.

AN EXPERIMENT ILLUSTRATING THE LAW OF MULTIPLE PROPORTIONS.

BY WARREN RUFUS SMITH.

Department of Chemistry, Lewis Institute, Chicago.

The advantage of illustrating the fundamental laws of chemistry by simple quantitative experiments in the laboratory is now generally recognized. In the case of most of these laws suitable experiments are easily devised, and satisfactory directions can be found in any modern laboratory manual. In the case of the law of multiple proportions, however, the majority of the suggestions for demonstrating the fact that "when two substances react in more than one proportion, the quantities of one that react with a given quantity of the other, bear a simple ration to each other" are either inexact or difficult of manipulation; or else they deal with substances with which the ordinary student is unfamiliar. Some time ago I devised an experiment which avoids these difficulties to a degree, and which, so far as I know, has not hitherto been published in any text-book or periodical.* I have used this experiment with good success in both academic and collegiate classes, and it has found favor in at least one laboratory other than my own. The directions are as follows:

Sodium carbonate and hydrochloric acid react in two different ways. The end reaction in one case may be apparent by using methyl orange as an indicator; in the other case by using phenolphthalein. Familiarize yourself with the colors given by methyl orange in acids and alkalies.

Put about 100 cc. water into a beaker. Add a few drops of methyl orange solution. Run in from a burette a known quantity of sodium carbonate solution. Titrate with hydrochloric acid. Add the hydrochloric acid slowly toward the end, keeping the solution well stirred. Repeat this

* An outline of this experiment is given in Congdon's *Laboratory Instructions in Chemistry*, page 95.—Editor.

work until you get two results that correspond with each other. Arrange the results as in the preceding experiment.

Then repeat this work, using phenolphthalein in the place of methyl orange. The hydrochloric acid must be added very cautiously, keeping the solution well stirred so as to avoid effervescence. Arrange results as before.

Are the amounts of acid that react with a given quantity of sodium carbonate the same in the two cases? If not, is there any simple ratio between them?

This experiment has immediately followed one illustrating the law of definite proportions, by the titration of acid with alkali, using phenolphthalein as an indicator so that the directions for manipulation are not as full as would otherwise be needful. The stock solutions are approximately normal. Students have obtained better results by working with solutions of this strength and diluting in the beaker than by using more dilute solutions directly.

A variation of the above experiment is to dissolve an indefinite amount of sodium carbonate in the beaker, add both indicators and titrate with acid. This method does not give as exact results in the hands of students, but, on the other hand, it is simpler, and the principle involved is more easily grasped.

TWO SIMPLE AND CONVENIENT GAS GENERATORS.

BY C. E. LINEBARGER.

I. The form of gas generator commonly used by students in elementary chemistry consists of a bottle or flask fitted with a two-hole stopper through which pass a delivery tube and a funnel or "thistle" tube. While such a generator is simple and inexpensive, it does not give a very regular flow of gas, and the "thistle" tube is rather fragile. The substitution of a stopcock funnel for the "thistle" tube makes the apparatus, however, all that could be desired. But stopcock funnels are too expensive for general use in the laboratory. Still one can be readily improvised by the student from his stock of apparatus, which answers very well.

A bit of rubber tubing about a centimeter long and of such a size as to fit rather snugly in the neck of the funnel, has a hole about a millimeter in diameter cut in its side near one end. (Fig.

1.) This is fastened securely in the neck of the funnel by means of a cement prepared by melting about equal parts of beeswax and rosin together. The neck of the funnel is cautiously warmed by holding it above a small Bunsen flame, and a little cement applied to it. The glass should not be warmer than just necessary to melt the cement. The rubber tube is heated a little in a flame, and then inserted in the funnel. When the glass is cold, the rubber is held very firmly, and may be removed at any time by warming the glass somewhat to melt the cement. A glass rod fitting rather tightly in the rubber tube completes the stopcock funnel. By raising the rod, more or less of the hole in the rubber tube is exposed, so that a liquid in the funnel can be made to flow or drop out with a speed which can be regulated very nicely. It is advisable to grease the rod with vaseline so as to prevent sticking and to insure a smooth action.

With such a stopcock funnel, the gas generator takes the form shown in Fig. 2.

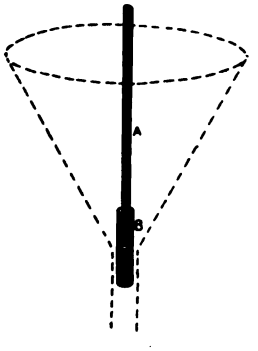


Fig. 1.

Fig. 2.

Of course, this generator cannot be used with any liquids which attack rubber, as strong sulphuric or nitric acid.

The generator just described has been in use in my laboratory for some time with most satisfactory results. It has especially been employed in the generation of *acetylene* by the action of water on calcium carbide, of *chlorine* by the action of concentrated hydrochloric acid on bleaching powder, and of *oxygen* by the action of water on sodium peroxide.

II. A generator which stands always ready to give a small current of hydrogen sulphide may be constructed as follows: A wide-mouthed bottle is fitted with a cork pierced with a hole just large enough to permit the passing with some friction of a test tube of ordinary size. The bottom of the test tube is cut off, and the end held in a flame until the edges fall together so as to render the end of the tube a little narrower than its diameter. A thin cork disk is perforated with several small holes and slipped into the test tube down against the ledge formed at the end of the tube. The mouth of the tube is fitted with a cork and delivery tube.

The bottle is partly filled with dilute sulphuric acid, and a couple or so lumps of iron sulphide dropped into the test tube so as to rest on the cork disk. By pushing the tube down so that the acid may enter and react with the sulphide, a current of hydrogen sulphide may at a moment's notice be obtained. By lifting the tube up out of the acid, the generation of the gas ceases.

In qualitative analysis, such a generator has proved very useful and convenient and the noisome nuisance of sulphuretted hydrogen has been much abated. With one charging it can be used quite a number of times.

Metrology.*

THE FIFTY-SIXTH CONGRESS AND THE METRIC SYSTEM.

BY RUFUS P. WILLIAMS.

December 4, 1899, at the first session of the Fifty-sixth Congress, Representative Littauer of New York, introduced into the House the following bill, H. R. 104, which was referred to the Committee on Coinage, Weights and Measures:

Be it enacted, etc. "That from and after the first of July, 1902, all the departments of the government of the United States, in the transaction of all business requiring the use of weight and

*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and from said first day of July, 1902, the metric system of weights and measures shall be the legal standard of weights and measures recognized in the United States."

January 10, 1900, Representative Shafroth, of Colorado, presented another bill, almost identical in wording with the previous, except that the dates were respectively January 1, 1901, and January 1, 1902.

Owing to the approaching presidential election, it was claimed, the committee thought best not to report either bill at the first session, 1899-1900. Early in the second session the committee selected the Shafroth bill, changing the dates for both government use and legal standard to January 1, 1903, and decided to report it favorably. This was December 6, 1900, and it gave rise in the leading papers to statements that a bill for the adoption of the metric system had been favorably reported in the House. It is understood that all the eighteen members—with possibly two exceptions—of the committee, of which Representative Southard, of Ohio was chairman, were in favor of the metric system and the passage of the bill. Still it was never reported (Cong. Record, February 1, 1901, page 1996).

The bills themselves have the merit of brevity, and each makes an exception—as it is probably wise to do—to compulsory use of the system in completing the survey of the public lands. They are the same in purport, the dates only being different. The final date chosen, January 1, 1903, would have given ample time for the departments of government to prepare for the change. The two special features of the bill to be noted are (1) compulsory use by the government, (2) establishment of a legal standard. There is no hint at compulsory use by the people except in their transactions with the government. The two departments most affected by the change would be the postal and the customs services. The pecuniary saving in the latter to the government would be very great as the reckoning of duties would require far less time than at present. While the postal department would be benefited to a smaller extent, the man who mails his letters and circulars would never know the difference, and the transactions

would be of the simplest sort. Who knows to-day whether his foreign letters are weighed by metric or avoirdupois weight?

Still the influence of government use could not be but beneficial to the people, who would gradually become educated in the use of the system and recognize its great superiority. A large metal manufacturer who employs both systems in his works, voices the best opinion when he says: "We are heartily in accord with the opinion that if the government should make the use of the metric system compulsory in all of its departments it would be very quickly adopted in business transactions, and we hope that some such scheme can be pushed to a successful issue." While this method of adoption does not seem to us to be the ideal one, nor is it the one usually employed by nations, it is probably the only one which, in the apathetic state of Congress, could become a law.

The second item in the bill—constituting the metric weights and measures the legal standard ones—deserves more than passing notice. It is not generally known that the system of weights and measures we use every day has never been legalized by act of Congress. The Constitution gives to Congress the authority to establish a standard, but the only general law relating to the subject is that of July 28, 1866, when the metric system was *legalized* by an act beginning: "It shall be lawful throughout the United States of America to employ the weights and measures of the metric system," etc. An act of 1828 made the Troy pound the standard of the mint, but this only applies to the weighing of the precious metals for coinage.

The law of 1866 legalizes the metric system and gives conversion tables, but does not establish any standard for general reference. In cases affecting the United States government reference is made to the International Prototypes—the meter and kilo—received from Paris January 2, 1890. Every State has its local laws to which individual cases must be referred, and these laws favor the old English system. Thus we have the anomaly of a double system. The passage of the Shafroth bill would have settled the question of *the standard* for all time. The committee, though professedly in favor of the bill, has made no movement looking to its enactment. The measure must now

be passed along to the Fifty-seventh Congress, and taken up by a new committee which may or may not favor a reform. At all events the same ground must be fought over as it has again and again in the past. But each session brings us a little nearer to the inevitable time when we, in common with every civilized nation, must adopt and use a system which is immeasurably superior to all others.

NOTES

The Metric System in Russia. Associated Press reports last autumn were to the effect that Russia had adopted the metric system, making its use compulsory after a certain date. Consul-General W. R. Holloway, of St. Petersburg, replying to the editor of this column, under date of Dec. 25, 1900, gives a translation of the latest order relating to the subject. This order is dated Aug. 20, 1899, and is, *verbatim,* as follows: "The metric system is allowed in the empire, as well as the Russian system of weights and measures, in all commercial dealings, contracts, estimations and undertakings, upon mutual agreement of both contracting parties, as well as in all dealings with the government's departments, offices and public administrations, if permission or order of the competent minister be granted, but on condition that private persons should not be bound by this order to deal with said departments against their will and without their consent."

It is understood that the ministry of finance is working upon a method for the adoption of the system in the empire.

Russia and the Gregorian Calendar. Under date of May 13, 1899, Consul-General Holloway, of St. Petersburg, writes as follows: "The Russian government has, after many years' discussion, determined to abandon the old style or Julian-Greek calendar, which is twelve days behind the now universal system of the Gregorian cycle, and which has been a source of annoyance to Russians doing business with other countries, who were compelled to use both dates, as well as to foreigners trading with Russia. The St. Petersburg Astronomical Society has taken the matter in hand, and with the co-operation of the ministers will appoint a commission to be composed of sixteen persons, nine of whom are to be members of the Astronomical Society, who will arrange all the details. It is expected that the new style calendar will go into effect in 1901."

Dec. 25, 1900, Mr. Holloway writes: "The committees are still 'wrestling' with the question of adopting the Gregorian calendar. No one familiar with the Russian habit of procrastination will venture a guess when they will probably report."

The following Abbreviations of Metric Units have been decided upon by the International Committee of Weights and Measures: *Length*: Kilometer, km.; meter, m.; decimeter, dm.; centimeter, cm.; millimeter, mm.;

micron, μ. *Surface*: Square kilometer, km.²; hectare, ha.; are, a.; square meter, m.²; square decimeter, dm.²; square centimeter, cm.²; square millimeter, mm.². *Volume*: Cubic meter, m.³; stere, s.; cubic decimeter, dm.³; cubic centimeter, cm.³; cubic millimeter, mm.³. *Capacity*: Hectoliter, hl.; decaliter, dal.; liter, l.; deciliter, dl.; centiliter, cl.; milliliter, ml.; microliter, λ. *Weight*: Tonne, t.; quintal metrique, q.; kilogramme, kg.; gramme, g.; decigramme, dg.; centigramme, cg.; milligramme, mg.; microgramme, γ. —*Scientific American.*

Notes.

BOTANY.

At the meeting of the Society for Plant Morphology and Physiology, held at Baltimore, Dec. 28, 1900, a committee was appointed, consisting of Messrs. W. F. Ganong, F. E. Lloyd and G. F. Atkinson, to take into consideration the formulation of a college entrance option in botany. This is of course in the line of the movement towards the unification of college entrance requirements for the relief of the schools and the promotion of education. The preliminary report of the committee is now ready, and copies may be obtained gratis by application to the chairman of the committee, Professor W. F. Ganong, Smith College, Northampton, Mass. The committee desires to obtain from secondary school teachers as full criticisms and suggestions as possible upon the report.

The Movement of Protoplasm in plant cells, while easily seen in the cells of onion and those of the leaves of *Elodea* (the little round-leaved water weed that grows in long strands), are much more striking in the latter plant, because the chlorophyll bodies are carried around with the current, thus making the motion more easily visible and better understood by high-school pupils. Several of the small leaves in active condition should be mounted in water under a cover glass and may then be warmed slightly by laying on the back of the hand for a moment. Activity is usually best found near the margin of the leaf where there are fewer cells. L. M.

Explosive Dehiscence. Every teacher can imagine how interesting it would be to take pupils to a field or garden where bean or pea pods were exploding in scattering their seeds. The same effect may be produced at the time when the class is studying the dehiscence of fruits and scattering of seeds, by preserving in a one per cent solution of formaline any pods that one may come across when they are ripe and just ready to burst. They will, of course, remain closed until taken out and dried. The pupil

may draw his first view of the pod while it is drying and then lay it aside for the next exercise in a place where it will not be disturbed, or he may hasten this operation by placing it in the sun or a drying oven. He can then draw it, showing the seeds thrown out and the mechanism that did it.

L. M.

Oxygen from Plants. In the experiment showing that oxygen is given off by water plants during photosynthesis, the evolution of the gas stops very soon. Some books advise the teacher to blow vigorously through the water. A more efficient way is to make from any ordinary bottle a gas generator, put in some fragments of marble and any kind of dilute acid to cover, seal it tightly with hot paraffine and let the gas generated pass through the water in which the plants are, being careful not to get it under the funnel arranged to collect the oxygen. With two or three applications of carbon dioxide in the above way, enough oxygen will be given off to test with a coaling splinter. L. M.

Of Plants for Aquaria the leafy pondweed (*Potamogeton foliosus*) gives perhaps as satisfactory results as the more usual forms. It readily fruits in the jars and if the nutlets be allowed to remain on the surface till time for them to sink, a fresh crop is assured for the following season. This season I find to be quite early, sometimes as early as December, if the aquaria have plenty of sunlight. Two other reasons make this species very desirable; under direct sunlight the giving off of oxygen is more rapid and profuse than in any other plant under our observation; algae do not make such natural trellis of these plants as they do of quite all of the species of *myriophyllum*. The latter case is partly due to the fact that snails can more readily keep the pondweed plants free from algal growths, for their surfaces are smoother and less complex. Another reason will be of interest to those who teach in buildings where during the winter season it is impossible to keep the laboratories comparatively near the daytime temperature, after the regular session. Plants (two or three inches) four to six centimeters long will readily withstand changes of temperature from day to night of (twenty-five or thirty degrees, F.) seventeen to eighteen degrees, C. The creeping stems of aquatics and their delicate water-roots are very well shown in these plants. E. L. M.

We are indebted to Dr. Muldrew for a copy of the very ingenious index of the trees of his district, and have found it all that is here modestly claimed for it, and much more. It has been put to the practical test, and given very good results. It is to be hoped that the author may undertake, at an early date, an extension of the same method so as to include wider limits. We regret that the condensed nature of Dr. Muldrew's paper has prevented his giving a detailed explanation of his plan of recognition of trees by their leaves. E. L. H.

PHYSICS.

Weight of Air.—An incandescent lamp useless by reason of a burned out filament can be employed to show that a body apparently loses weight because it is immersed in air.

Select a lamp in which you believe, after examining the tip, there is still a vacuum. Weigh it. Put it in a tin cup quite dry within, cover with a cloth and break with a hammer. Empty the fragments carefully upon the pan, where the intact lamp was. The weight-pan sinks. G. F. S.

Expansion of Metals. A striking lecture experiment to show the expansion of metals by heat is this: Support an iron wire about a yard long horizontally between two clamps. Pass a current from the dynamo through the wire until it becomes faintly red. On increasing the current the wire sags through perhaps two or three inches. On stopping the current, it rises and assumes again its original length. G. F. S.

The Determination of Density with a Trip or Platform Balance. The following method does not require the use of a frame to raise the balance above the table so that the solid may be suspended by a thread passed over the platform, and the work can be quickly accomplished. Place a beaker nearly full of water on the proper side for weighing and counterbalance it with sand, another beaker of water or anything convenient. Tie a thread to the solid and place it in the beaker of water, allowing it to rest on the bottom. Weigh and you have the weight in air. Now grasp the thread and suspend the solid so that it is completely submerged and does not touch the glass. Weigh and you have the "loss" in weight. Divide the weight in air by the loss in weight and the result is the density of the solid.

Calumet High School, Chicago, JNO. D HULLINGER, JR.

The Velocity of Light has been recently redetermined by M. Perrotin (Comptes rendus. cxxxi, 731), of the observatory at Nice, the method being Cornu's modification of Fizeau's toothed wheel. The distance between the two stations was 11 862,22 meters; the source of light was an electric lamp of 16-candle power; the wheel had 150 teeth. Every observation was made with increasing and decreasing velocity of rotation of the wheel, and the mean of both values taken. Nearly 1,500 measurements were taken during the course of a year, and it was found that the velocity of light in a vacuum is 299,90 $\pm$ 0.08 thousand kilometers per second, a value differing but slightly from that obtained by Michelson.

The Melting Point of Gold was determined by L. Holborn and A. Day (Wied. Ann. (4) 4, p. 99. 1901) by means of a thermocouple. Four hundred and fifty grams of gold were melted in crucibles of graphite, of porcelain or of clay, exposed to atmospheres of carbon dioxide, oxygen or air, and the temperature of solidification measured. The average of their

results was 1,063°.5 C., which is quite near to the value found by Heycock and Neville, viz., 1,061.7° C.

PHYSIOGRAPHY AND GEOGRAPHY.

Controlling the Lower Mississippi. James A. Sheddon, in a paper recently read before the Western Society of Engineers, proposes a new plan for controlling the water of the lower Mississippi, which in outline is as follows. At flood stage a large amount of water will be diverted from the river into enormous reservoirs, from which it can be drawn off at lower stages of the river. The reservoirs would be located in the St. Francis basin, near Cairo, which when cut across by low levees is estimated to have a capacity equal to the entire maximum discharge for thirteen days of the river at Cairo. The area flooded would be about 4,000 square miles—about half the area of Massachusetts. The cost is roughly estimated at $32,000,000, which is not excessive if one takes into consideration the fact that the present methods of controlling the river's flow by means of levees along its banks has proved but partially successful and has already cost more than $40,000,000. The new plan certainly deserves careful consideration.

Influence of Gulf Stream on Climate of Northwestern Europe. H. M. Watts (United States Weather Review, September, 1900) combats the common statement that the climate of northwestern Europe is profoundly modified by the Gulf Stream. He says: "By itself alone the Gulf Stream has as much effect on the climate of northwestern Europe as the fly in the fable had in carrying a stage coach up a hill." "The entire surface of the Atlantic Ocean north of the trade winds—or, rather, north and west of the center of the great Atlantic anticyclone—is drifted to the northeast by the prevailing aerial drift, which drift and not the ocean currents carries the beneficent influence of the ocean over the European islands and the shores to the east and northeast."

A similar error is made respecting the influence of the Japan Current upon northwestern North America. G. F. S.

It is interesting to note that the beginning of the twentieth century will see the most strenuous efforts that have ever been made to explore the polar regions. In the Arctic region there will be four parties—Peary, Sverdrup, Baldwin and a Russian party—and in the Antarctic the two splendidly equipped expeditions of Germany and England.——Captain Hecq, in a paper recently read in Brussels, furnished convincing evidence of the shrinking up of Lake Tanganyika. He found a few months ago, on visiting the station of Karema, which was built twenty years ago on the shore of the lake, that the water was now at a distance of fourteen miles.——Bulletin No. 232 of the United States Weather Bureau gives the views of the prominent meteorologists of the past century upon the West Indian hurricanes and describes the most important of these which have

occurred during the last twenty-five years. Charts showing the hurricane tracks for each month during the past twenty-two years are also given. The "Galveston storm" of last September is discussed. The report is not technical but is readable for non-experts.——In the February number of the *National Geographic Magazine* Mr. Henry Gannet, in discussing an article by Mr. Henry Ward Turner on the Origin of the Yosemite Valley, says: "It is perfectly obvious to those familiar with glacial phenomena that Yosemite is quite an ordinary and necessary product of glacial erosion, under the conditions prevailing in that locality. The main glacier came down Tenaya Canon, cutting it to a steep but fairly uniform grade. Yosemite Valley is but a continuation of that gorge." This is in opposition to Mr. Turner's views, who seems to consider it a result of aqueous erosion, aided by a system of fractures in the granite.——The Trans-Siberian railway, which is nearing completion, will greatly reduce the time of travel to the far East. From London or Paris to Shanghai will take but sixteen days, instead of over forty, and will cost less than half as much as now. This will make it quite possible to take a trip around the world during a summer vacation. W. H. S.

Book Reviews.

A Textbook of Geology. By ALBERT PERRY BRIGHAM, A.M., F.G.S.A., Professor of Geology in Colgate University. 13x19 cms., x and 477 pages. D. Appleton & Co., New York. 1901. $1.40.—It is always a pleasure to a teacher to find a textbook in which it is apparent that the author has met the difficulties of actual instruction and has a solution for them in his book. This book is striking in the fact that it never loses sight of the pupil's needs and point of view; it is not a mere collection of geological facts from which the student may get what he can, but it is also a guide to the understanding of these facts. The hand of the teacher is evident at every point helping the student to a clear comprehension of the broader generalities of the subject. Withal the book is decidedly readable, holding the attention throughout.

The ground covered is that usual in works on geology and the order of treatment is much the same. To the normal school instructor who desires to use this excellent text it may seem necessary to do a little rearranging. The tendency in such schools is to insist that the work in geology and physiography shall have a very direct bearing on geography, and he may find the land forms treated in portions of the book rather

remote from the genetic causes. For instance, rivers, their life histories and surroundings, are treated on pages 37-78, while completed drainage structures are treated on page 251. Glaciers are treated on pages 92-109, glacial hills on page 266, and much of the effect of glaciers on almost the last page of the book.

Professor Brigham has given us the best book in size, scope and treatment of any book on the subject on the market for secondary schools and colleges.

The work of the publisher is well done and the author is to be congratulated on his choice of illustrations, many of which are from photographs made by himself. The great trouble with photographic reproductions is that they lose all detail and character when the plates are a trifle worn: the pictures in this book are excellent and of a character that will prevent this defect appearing in most cases. E. C. CASE.

An Elementary Experimental Chemistry. By JOHN BERNHARD EKELEY. 13x19 cms., viii and 252 pages. Silver, Burdett & Co., New York. 1900. $.90.—This book is divided into three parts. Part I, of 85 pages, is devoted to sixty-five well selected experiments, usually found in all chemistries, illustrating the preparation and properties of the elements and their principal compounds. Chemical symbols, formulas and equations are not used in any way.

The laws and theories of chemistry are studied by means of twenty-eight experiments, nearly all quantitative, and comprise the subject matter of Part II. Here chemical symbols, formulas and equations are introduced; the graphic as well as the empiric receive attention.

In Part III sixty-four pages are given to the history, occurrence and the industrial applications of the principal elements and compounds. These are brief notes, well selected and interesting.

Part II contains many experiments entirely too difficult to be required of high school pupils. This part is ideal, but impractical. No criticisms are offered on the *parts* of the book. It is doubtful if the experiments could be improved. The severest criticism is upon the arrangement of the parts. It is true that teachers generally agree that the method of personal investigation is the best in the study of the natural sciences, and some would even say: "In the laboratory let the laws be rediscovered by the pupils themselves." About ten years ago the pendulum swung almost to its limit in this direction and then the "time limit" proved to be the insurmountable obstacle to these idealists.

I will not place Professor Ekeley with these extremists; yet I do believe he is wasting time with Part I when he asks the pupils to perform those sixty-five experiments before he takes up the discussion of the constitution of matter. With a very few experiments I believe the pupil can be made ready for the Atomic Theory, and after that grand conception is mastered, with its attendant laws, the rest of the experiments mean a hundred times more to him, and every chemical equation emphasizes it.

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The average class, equipment and amount of time given to chemistry on the school program—all make this an impractical text for most schools.

Denver, Colo. H. V. KEPNER.

Flame, Electricity and the Camera. By GEORGE ILES. 15x23 cms., 398 pages. Doubleday & McClure Co., New York. 1900. $2.—"With the mastery of electricity man enters upon his first real sovereignty of nature. As we hear the whir of the dynamo or listen at the telephone, as we turn the button of an incandescent lamp or travel in an electromobile, we are partakers in a revolution more swift and profound than has ever before been enacted upon the earth."

This opening sentence of another "century end" book gives the keynote of the style of language and enthusiasm with which the writer develops his theme. The plan of the book is systematic. The first hundred pages tells of the earliest records of man's fire-kindling and its use as his servant. It has given him warmth and artificial illumination; has created for him a home; has furnished it with pottery, and has molded for him metal ornaments and useful vessels.

Its greatest work, however, is the power it develops through the medium of the steam engine.

The writer then follows through two hundred and fifty pages or more with the development of the electric current and its applications. He touches the peaks of the development in heat, light, power, batteries, land and ocean telegraphy, the telephone, and discusses the problems of the future.

The treatment of photography, which occupies the closing chapters, is especially noteworthy. Much material has been collected, here, that is not so accessible in any other form. The advance from the old Daguerre process to the dry plate and the color photography of to-day is a great one.

The illustrations are numerous, the plates of Volta, Lord Kelvin and Edison being especially good.

While much matter contained in the book is collated, a spirit of advancement that is refreshing is breathed into every chapter.

In the Appendix the writer's remarks are most pertinent. So well stated is the closing paragraph that we deem it worth while to quote it here for the benefit of those who have not nor do not care to read the book as a whole:

Above and beyond any particular gift of science—a new chemical element, a ray of new penetration, or even a new rule of physical and chemical action—there has been evolved something more and greater; nothing else than perfecting the instrument by which discovery carves its path and particular rules are merged into universal law, the scientific method, now confessed the one trustworthy means for the winning of all truth. Beginning in the comparatively simple sphere of natural science, it has passed to the more difficult fields of art, history and criticism, to reforms social and political, moral and religious. In all its work, whether it has to do with the mere machinery of the livelihoods or with the things of the mind and heart, the conscience and the will, it means reality, accuracy, fidelity to the directly observed and carefully comprehended fact. It disregards

tradition, legends and guesses, however closely associated with great names or hoary institutions. In their stead it is erecting a new authority, which finds its sanctions in knowledge, in observation, experiment, reasoning, in untiring, impartial verification. When it gives play to the imagination and offers a conjecture in the hope that it may be helpful, the conjecture is plainly labeled as such and is withdrawn the moment that a sound objection so demands. The man of science ever rejoices when he finds, as he often can, that men of old had a forefeeling of modern scientific truth; but under all circumstances he fully declares exactly what he discovers, however much his disclosures may cause a valued heritage to be disprized. Triumphs to us inconceivable doubtless await the centuries to come, but there will remain as the inalienable glory of the nineteenth that to the old question, What is truth? it first gave not the old answer, Whatever has been so considered, but Whatsoever can be proved.

The Chicago Institute. C. W. CARMAN.

Plant Studies. An Elementary Botany. By JOHN M. COULTER, A.M., Ph.D., Head of Department of Botany, University of Chicago. 13x19 cms., 392 pages. D. Appleton & Co., New York. 1900. $1.25.

This is the Botany of the series of "Twentieth Century Textbooks" now being issued by Messrs. Appleton. The firm has done its work well. From a mechanical standpoint these books are all beautiful—presswork, paper, etc., being of first-class order. The contents of this modern Botany are what one would expect from Dr. Coulter, interesting, scholarly and up to date. Abundant use has been made of the modern photo-processes to illustrate the ecological side of the subject. The teacher who desires to study plants as "living things" ought to have the book. It deserves the highest praise.

As indicated in the preface, the book is intended for reading and study in connection with laboratory and field work.

The landscape illustrations will bear careful study. They form a very interesting feature of the work.

Those of us who have been looking forward to the time when the "why" element should have its proper place in botanical teaching ought to feel grateful to author and publishers for the excellent service they have done us in producing a book in which ecology has its proper place.

E. L. HILL.

Animal Life. A First Book of Zoölogy. By DAVID STARR JORDAN, Ph.D., LL.D., President of Leland Stanford Junior University, and VERNON L. KELLOGG, M.S., Professor in Leland Stanford Junior University. 13x19 cms., 329 pages. D. Appleton & Co., New York. 1900. $1.20.

This is the Zoölogy of the "Twentieth Century Series" and uniform in style with the others of this valuable series, of which the Astronomy has just appeared. The statement made in the preface gives one a good idea of the book:

The authors present this book as an elementary account of animal ecology—that is, of the relations of animals to their surroundings and of the responsive adapting or fitting of the life of animals to their surround-

ings. The book treats of animals from the point of view of the observer and student of animal life who wishes to know why animals are in structure and habits as they are. The beginning student should know that the whole life of animals, that all the variety of animal form and habit, is an expression of the fitness of animals to the varied circumstances and conditions of their living, and that this adapting and fitting of their life to the conditions of living come about inevitably and naturally, and that it can be readily studied and understood. The ways and course of this fitting are the greatest facts of life, excepting the fact of life itself.

The book is well calculated to make the young student an independent observer, and treats of that side of the subject most likely to hold his attention.

The illustrations are admirable. Here again photography has been most helpful and has been most wisely used.

The authors have given us a book that ought to make the subject interesting to the dullest student. E. L. HILL.

A Manual of Elementary Practical Physics. By JULIUS HORTVET, B.S., Teacher of Physics in the East Side High School, Minneapolis. 14x20 cms., xi and 255 pages. H. W. Wilson, Minneapolis. 1900. $1.—In many respects this is an eminently satisfying work. The discussion of the theoretical basis of each experiment is given with unusual completeness and clearness, and the questions and numerical exercises are very suggestive and helpful. The detailed descriptions of apparatus and minute directions for work would seem to afford the pupil all necessary instructions for securing excellent results.

The space given to the various topics shows that the author has exercised independent judgment in making his selections.

Topic.	Pages.	Experiments.
General introduction	14	..
General measurements	37	8
Mechanics	49	8
Sound	11	2
Heat	30	6
Light	32	7
Electricity and magnetism	63	13

Since the author professedly includes only the experiments which constitute the work of his own classes, it may seem uncharitable to criticize the book unfavorably for what it omits, yet it does seem unfortunate that he did not feel able to include a larger number of experiments, so that other instructors could select the work best suited to their needs and equipment. Some omissions will doubtless appear quite serious to most physicists. Thus there are no experiments bearing at all directly on conservation of energy, and none on electro-magnetic induction—two subjects that would seem decidedly fundamental. For those who can use just the experiments given in this work nothing better can be asked. The quality of the book is beyond adverse criticism.

Lake View High School, Chicago. A. W. AUGUR.

Books Received.

Foundations of Botany. By Joseph Y. Bergen, A. M., Instructor in Biology, English High School, Boston. Ginn & Co., Boston, 1901. xi and 412+257 pages. $1.50.

Lessons in Nature Study. By Oliver P. Jenkins and Vernon L. Kellogg. The Whitaker & Ray Co. 1900. 195 pages.

Proceedings of the Annual Conferences of the State Science Teachers' Association. 1897 to 1900.

The Elementary Principles of Chemistry. By A. V. E. Young, Professor of Chemistry in Northwestern University. D. Appleton & Co., New York, 1901. xiv and 252+106 pages. $1.10.

Suggestions to Teachers designed to accompany the Elementary Principles of Chemistry. By A. V. E. Young, Professor of Chemistry in Northwestern University. D. Appleton & Co., New York, 1901. iii and 48 pages.

A Text Book of Geology. By Albert Perry Brigham, A. M., F. G. S. A., Professor of Geology in Colgate University. D.Appleton & Co., New York, 1901. x and 477 pages. $1.40.

A Text Book of Astronomy. By George C. Comstock, Director of the Washburn Observatory and Professor of Astronomy in the University of Wisconsin. D. Appleton & Co., New York, 1901. ix and 391 pages. $1.30.

CLEARING HOUSE.

Teachers desiring to offer for exchange books, apparatus, etc., may insert a notice to that effect at the nominal rate of one cent per word, *in advance*.

Several *Curry's Classics for Vocal Expression*, unused, $1.25, for any recent text books worth $1.00 or more. Send book or make offer.—*High School, Easthampton, Mass.*

Reports of Meetings.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The twenty-ninth meeting of the association was held in Boston, Mass., March 2, 1901. After the usual routine business the annual report of the secretary was read. The report was mainly a *resume* of the printed reports of the previous meetings and showed in a striking manner the vast amount of work done by the members, especially in preparing and circulating helpful information on the teaching of physics. The treasurer reported an unexpended balance of about $200. The committee on current events gave an abstract of several articles on submarine and aerial navigation. The committee on current literature distributed a printed list of the titles and sources of about seventy magazine articles on physics which had been published since the November meeting.

The following officers were elected for the current year: President, H. J. Chase; vice president, L. J. Manning; secretary, F. R. Hathaway; treasurer, George A. Cowen; three additional members of the executive

committee, J. W. Hutchins, A. L. Kimball and William H. Snyder. A single vacancy in the membership (which is limited to fifty) was filled by the election of Dr. Lyman C. Newell.

After lunch the association listened to an address on "The Professional Training of the Teacher of Physics," by Dr. Edward B. Rosa, Professor of Physics, Wesleyan University, Middletown, Conn. He said, among other things, that the teacher of physics should be well trained, but need not be a specialist in order to be a successful teacher. His training should come from two sources—his college course and actual teaching. The college work should be inclusive enough to cover (1) the facts, phenomena and general principles of physics, (2) sufficient mathematical physics to apply calculus, (3) a generous amount of laboratory work, (4) experience in the use of journals. His teaching should include (1) persistent, judicious reading of original articles and the best books, (2) acquisition of skill in making and repairing apparatus, (3) performance of some research work. He urged the members to keep well in advance of their classes and to set a high standard both for their pupils and for themselves.

This address was followed by a symposium on "Successful Methods and Devices for the Lecture Room." Among the devices shown were an adjustable laboratory table, several diagrams to illustrate the method of teaching young pupils about a hot-air furnace, and two simple pieces of apparatus to be used with the lantern in illustrating some effects of an electric current. After the symposium a paper was read on "Physics in the Boston Evening High School." Notice was given of a proposed amendment for an extension of the membership limit. The meeting then adjourned to give an opportunity for examination of the lecture devices and for social intercourse.

Reported by LYMAN C. NEWELL.

Correspondence.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion as well as answers to the questions of others. Those of sufficient merit and interest will be published.

11. How should the study of bacteria be presented to high school classes?

12. Is there a sufficient constancy in the proximity of the micropyle on seeds and the tip of the caulicle to use this as a method of finding the micropyle in doubtful cases? Is there any phylogenetic significance in this position of the caulicle?

13. Should a teacher in a secondary school teach his own research work during a year's course in any science, to the detriment of the student's best broad knowledge of the subject?

14. How and to what extent can the natural sciences be best interrelated?

15. To what extent should teachers of one science be acquainted with the other sciences?

16. How and to what extent should the history of a science be taught in an elementary course?

17. Are high school pupils capable of taking lecture notes in science instruction understandingly and with profit?

18. What is the proper place of physical geography in the high school curriculum?

19. Has any teacher of chemistry had his students use Jena glass? If so, has it been found to last longer than the ordinary Bohemian glass?

20. Can the elements of agriculture be profitably substituted for a part of the high school course in botany?

DISCUSSION OF QUESTIONS.

2. Considered from a biological standpoint, what constitutes a "good drawing"? Which is the better criterion by which to judge of a student's work in biology—a good drawing or a good description?

From a biological standpoint a "good drawing" should show faithfully all the structures observed *after* careful study, or if the phenomenon is to be interpreted, such portions as are necessary; the power of discrimination of the more or less important should also be shown in the drawing, and the same would be desirable for apparatus used to demonstrate and explain some nature phenomena. A good drawing is in some cases better to judge of the student's work than a good description, but for most problems a combination of the two is preferable.

Hyde Park High School, Chicago. W. R. MITCHELL.

Before offering answer to this question, I freely disavow any disparagement whatsoever of the regular instruction or its results given or gotten under the courses in drawing or art usual in the secondary schools of this country, because the immediate results are quite purposely considered from another point of view than those involved in this question.

First, from the biological standpoint, a "good drawing" represents the characters of the specimen under observation. A drawing of another quality in the majority of cases only suggests them, or frequently suggests the location of their possibilities merely. A good drawing, if the laboratory work is well conducted, proves that the student has made observations of the individual characters. A sketchy one indicates that he has the general idea, but it indicates nothing further. This general idea in many cases is gotten carelessly, but the good drawing can never be gotten under that mental attitude. Keen observation and as keen judgment are necessary for the representation of the details. These two are a part of the object of science study in secondary schools. Then, in the laboratory of the school as well as in the laboratory of the specialist of many years' experience, the drawing which is adequate, from the biological standpoint,

is the one which is a *copy* of the specimen or the structure under consideration.

Second, if a choice is to be made between drawing and description, the teacher must appreciate the balance which exists between the special point of view from which the two criteria are adopted. The value of the good drawing rests on the principle cited in the above paragraph. The value of a good description rests on a much more complex principle. Under the ordinary circumstances under which biology is taught, the pupil does not go at the work entirely on his own resources. He has at his hand a laboratory guide in some form or he has had directions more or less complete from the teacher. From these he is bound to take a cue, and he will frame his description more or less closely on this cue according to the completeness of the directions followed. Science work in our schools is not merely cultural, but it is primarily training work. It is work the training from which is to stand the young person in good stead when he has left school for his walk in life. A good drawing represents his biological facts. Biology, as a pure science, is cultural. A good description requires correct use of the language. Adequate and accurate language require a broad and full vocabulary with a mental recognition of the value of words. These come after faithful training. These are the tools of every day's work throughout his life. To make a choice between these criteria, then, the teacher must purposely choose between the cultural and training value and purpose of the course under his direction. To make a broad and proper balance between them is to recognize the fuller value of combining and training and culture. The old method was to cram the mind with facts and leave the training to experience, often bitter. Of late there has been some tendency to overtrain while the retention of facts has been overlooked. The happy medium is to develop both, merging and conforming both to the greatest fitness for the pupils' life work.

E. L. M.

6. What minerals are suitable for "unknowns" in elementary qualitative analysis?

I am always happy to aid any one who is so wise as to use ***natural*** mixtures in chemistry. The student learns to know a mineral at the same time he learns the analysis. Those which I have found useful are: Galena and other lead ores, pyrite, sphalerite, limonite in varying forms, hematite in varying forms, siderite, apatite, barite, gypsum in varying forms, calcite in varying forms, malachite and other copper ores, chromite, pyrolusite and other manganese ores, quartz with free gold, halite, cryolite.

Preparatory School of University of Illinois. E. G. HOWE.

I submit the following list of minerals suitable for "unknowns" in elementary qualitative analysis, with the remarks that, while the common metals of the groups are all represented, necessarily all the acid radicals are not, and that these minerals may all be bought from the dealers at comparatively low prices:

Galena, PbS, fine granular preferred; cerussite, $PbCO_3$; anglesite, $PbSO_4$; pyrymorphite, Pb_4 (PbCl) $(PO_4)_3$; wulfenite, $PbMoO_4$; crocoite, $PbCrO_4$; argentite, Ag_2S; pyrargyrite, $3Ag_2S$. Sb_2S_3; proustite, $3Ag_2S.As_2S_3$; stephanite, $5Ag_2S$ Sb_2S_3; cerargyrite, AgCl; cinnabar, HgS; calomel, HgCl; coloradoite, HgTe: realgar, AsS; arsenopyrite (mispickel), FeAsS; stibnite, Sb_2S_3; cassiterite, SnO_2; stannite, Cu_2FeSnS_4, a sulphide of Sn, Cu, Fe and sometimes Zn; tetradymite, $Bi_2(Te,S)_3$; chalcopyrite, $CuFeS_2$; chalcocite, Cu_2S; bornite, Cu_3FeS_3; malachite, $CuCO_3.Cu(OH)_2$; cuprite, Cu_2O; chrysocolla, $CuSiO_3$; greenockite, CdS: kaolinite, $H_4Al_2Si_2O_9$, (insoluble); orthoclase, $KAlSi_3O_8$; corundum, Al_2O_3; cryolite, Na_3AlF_6; wavellite, $(Al\ OH)_3$ $(PO_4)_2.5H_2O$; bauxite, $Al_2O_3.2H_2O$; chromite, $FeCr_2O_4$: magnetite, Fe_3O_4; hematite, Fe_2O_3, becomes magnetic on heating B. B.: siderite, $FeCO_3$; smaltite, $CoAs_2$; cobaltite, CoAsS: millerite, NiS; niccolite, NiAs: pyrolusite, MnO_2; rhodocrosite, $MnCO_3$; rhodonite, $MnSiO_3$: sphalerite, ZnS; smithsonite, $ZnCO_3$: barite, $BaSO_4$; witherite, $BaCO_3$; celestite, $SrSO_4$: strontianite, $SrCO_3$; calcite, $CaCO_3$; fluorite, CaF_2: gypsum, $CaSO_4.2H_2O$: dolomite, $MgCa(CO_3)_2$; talc. $H_2Mg_3Si_4O_{12}$: albite, $NaAlSi_3O_8$; borax, $Na_2B_6O_7$. $10H_2O$; halite, NaCl: sylvite, KCl; niter, KNO_3.

O. E. PAGIN.

Asst. U. S. Att'y, N. Dist. Ill.

8. To what extent should the English of laboratory notes be corrected by the science teacher?

The science teacher should note and correct errors of language used by students, and constantly point out the mistakes in spelling, capitalization, important punctuation and false expression of facts.

Hyde Park High School, Chicago. W R. MITCHELL.

Emphatically, to no extent! Barely one pupil out of a hundred profits appreciably from the corrections made in his work by the teacher. But there is another side to the question—and it is highly important. Language is the vehicle of ideas. To express laboratory observations and conclusions in English which is wrong or even in poor taste is as bad as to sing a religious hymn to the lightest opera. Scientific studies are adapted to produce in the student exactness. What a comment on the object and the method if the laboratory notes are allowed to pass when they would force the instant removal of the teacher if the same papers were an unmarked exercise in English! The teacher should indicate every error or lack of judgment in every paper in science, whether in the subject of the department or in English or other language; and the student should be required to correct every mistake, thereby directing his own attention to the correct usage. The only teachers in any secondary school science whom I have heard objecting to this principle are a few teachers who do not and can not (from continued habit) use correct language in connection with their school work. E. L. M.

10. What proportion ought to be given to morphology, physiology and ecology? Does either possess superior educational value?

The teachers' questions should be discussed by more than one teacher that we may have different points of view. The question of the relative amount of time that should be given to morphology, physiology and ecol-

ogy, and the relative value of each, is a rather broad one and I do not attempt to more than give my opinion.

Since the systematic work of former teaching has been replaced by morphology there has been a new turn in favor of a large proportion of the study to be in the field, or of the nature of field work.

This is now ecology, and as it is only a subdivision of the broader subject of physiology the former need not be separately discussed, for what is said of the latter will also hold for the former.

As to the value of morphology, the answer would depend somewhat on what is meant to be included. Of the two departments of this study, I should say that minute internal anatomy has very little place in a high school course, but external form and general structure are of the utmost importance as a foundation for much of the other work to be done. Yet it must be admitted that, for the younger student, only so much structure as is necessary to understand functions is all that it is profitable to study. Added to this that the study of structures alone is less interesting than that of the actions of living things, that it is mostly observational, and though it may be made also comparative it develops the pupil somewhat one-sidedly, and we have reasons for devoting least time to morphology.

Physiology, on the other hand, if properly taught, calls into play not only the faculty of observation, in noting the phenomena of the activities of living things, but in the course of making experiments for the study of these phenomena it is indispensable that comparison and judgment be exercised, through which finally conclusions are reached, and so the whole mental process comes into play.

All this holds true for the observation of the individual plant or parts of any organism, even, and when the same exercise of powers is carried into the field for observing phenomena on a larger scale—ecological—where a much greater number of data, and on a larger scale, must be collected, and the comparisons include so much more, as will also the conclusions embody more, we have a study that is educative in the wider sense. Not only this, but the pupil comes in contact with phenomena of nature that have a direct bearing on the meaning of the existence of things—world evolution—and so he will come nearest to one of the most important phases of his education—man's position in nature and the significance of his existence.

It will not be hard to see from the above that the more important and therefore the study to which the greater amount of time should be given is, first, physiology, including ecology; and next to this, perhaps less than one-fourth the time, to general morphology.

So far nothing has been said of another side, and that is the study of relationships. It should not by any means be neglected, for without it the student's knowledge is incomplete. In our course in botany we usually have pupils study from five to ten plants as to their relationships.

L. M.

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OUT-DOOR SCIENCE IN SECONDARY SCHOOLS.

BY FREDERICK A. VOGT.

Principal of the Central High School, Buffalo, N. Y.

The first step to take in teaching science to young people and in popularizing the study among older people is to throw away much of the traditional polysyllabic phraseology and use a little common sense and good old Anglo-Saxon now and then—to teach nature, instead of science.

There is not only great danger in being too technical, but in telling too much. We all like to talk on our pet subjects. We rattle along, airing our opinions and pouring out big volumes of knowledge, and expect the poor pupils, like great dry sponges, to absorb the gracious gift. But they don't absorb it; it isn't their business; they belong to quite another sub-kingdom; and while we are just about to congratulate ourselves on our facility of expression and wise beneficence, we are rudely made aware that our eloquence was all lost; and, worse still, we have been guilty of repression, of stifling natural curiosity, and crushing what might become a priceless, inquiring, intellectual habit.

Is it any wonder that so few ever go on with their geology, mineralogy, botany, or zoölogy, after they leave school? What is our object as teachers? Is it to cram geology and botany down passive throats in one or two school terms, or is it to lead our students so gently and awaken so keen a desire that they shall study these sciences all their lives, to be a never-ending joy, a pure pleasure and a solace amid coming cares and darkening days?

So much for the language of the teacher, and now for the

means of giving reality to his teaching efforts. This can only be done by the laboratory method or investigation in the field. With the latter, out-door work, only, does this paper especially treat.

ACTUAL CONTACT WITH NATURE.

While I do not for a moment decry the use of books, either for collateral reading or for text-books—in fact, I plead for a wider reading and profounder study of the best scientific writers—still, I feel just as you must feel, that there is something radically wrong in much of our science teaching, and that we have come to regard books as more real than the earth, the sky, the rocks, the plants, and the animals, which are all about us.

Just why this is so, I am unable to understand. Nature is so lavish! On all sides, easy of access, are the phenomena and the realities, while the school-room is artificial, and the teacher, alas, in perfect keeping with the school-room.

Can it be that pupils are averse to actual contact with nature? Not at all. From the earliest childhood throughout life there is, in most persons, a remarkable turn toward curious investigation and thorough understanding of the things of nature. That I know from my own experience while teaching in the grammar schools.

One day I asked the pupils to bring me in any specimens of stones they might find in the vacant lots and the fields; and then I promised to give them a talk about these stones. I expected perhaps twenty or thirty specimens. What was my amazement and secret horror when, the next day and the next, came dozens and dozens of specimens, until in a few days I had over a ton and a half, containing 3,000 specimens. There were granites, gneisses, and schists, and quartzes; there were sandstones, slates, shales, limestones, glacial scratchings, marbles, and onyx; there were geodes, crystals, ores, stone hammers, arrow-heads, brick-bats, furnace slag, and fossils. I took everything smilingly, and at night the janitor and I buried many duplicates and the useless stuff in a deep hole where they wouldn't be likely to get hold of it again.

We soon possessed an excellent cabinetful, and had fine times talking about the making of stones—the crust of the earth—

former inhabitants, the great ice age, and such simple geology as they could understand; and they did understand; that did not end it. We studied plants in the same way; physics and chemistry, with home-made apparatus. Of course, it all took time, and a good deal of it, and there wasn't any extra pay for it, either; but there are labors whose recompense is far more precious than dollars and cents.

And so I find enthusiasm also for out-door science, among secondary pupils and among the great body of intelligent people of our cities; and if nature is so accessible, and pupils are so eager for its secrets, and we still worship books and ignore the visible objects and forces so freely at our disposal, there is no other conclusion to arrive at, except that the teacher himself is either too ignorant or too indolent to make proper use of them. It takes time; it needs enthusiasm; it needs a genuine love for the subject in hand, and a profound interest in and sympathy with the student.

The subjects in which field work may be made very useful are geography, geology, botany and zoölogy, and the objects are of course apparent to all. First, it cultivates a familiarity with nature, which is wholesome and desirable. We are living in an artificial age. Children nowadays get too much pocket money; there is too much theater; too much smartness; too much flabbiness for the real business of life; too much *blase* yawning; too many parties; too much attention to dress, the color of the necktie, the crease of the trousers, or the make of a gown. The only meaning science has for many of the richer classes is the curved ball of the pitcher, the manœuvers of the quarterback, or the manly art of self-defense.

I know of nothing that will counteract the indifference of parents and lead the young mind back to a simpler and more humanizing condition of life than to make it familiar with old mother earth, the stream, the valley, the tree, the flower, and the bird.

CORRECT OBSERVATION.

Another object of field work is to train habits of correct observation. Pupils ordinarily take too much for granted. They will swallow anything that is printed in a book, or that the

teacher may choose to tell, always providing the pupil is sufficiently awake to perform the function. It is hardly an exaggeration that they would believe the moon was made of green cheese, providing the statement came with august solemnity from the teacher's chair. There is too hasty generalization and a prevailing unwillingness to careful examination. Careful field work opens the eye and corrects much of this slovenly mode of thinking; creates honest doubt and questions an unsupported statement. The pupil wants to see the pollen on the bee before he believes in cross-fertilization; he wants to see rocks actually in layers before he will believe they could have been deposited in water, and he pounds up a fragment of sandstone to get at the original sand; he wants to see the actual castings before he will believe all that Darwin says about his wonderful earthworms; and few things escape the eye of the pupils who go out with the understanding that it is business and their duty to observe and take notes.

THE THINGS THEMSELVES.

Another object of field study is to see life in its environment. Stuffed birds and animals in cases are all very good; shells look pretty behind nice glass doors, and herbaria play a very important part; yet, after all, how much better to see a thrush's flight; to hear the pewee's song; how much more satisfactory to watch a snail creep and feed; how much more delightful to study the blossoming hepatica; to note its various leaves, its soil, its surroundings, and discover why it blooms at the very opening of springtime.

More can be learned from a handful of pebbles on the beach than a whole book written upon the same subject.

Yet another object is to acquire specific information not contained in books. The feel of a leaf, the odor of the honeysuckle or the pine, the cry of the kingfisher, the locomotion of a horse, and the locomotion of a cow, the formation of miniature gorges in a rainstorm, and the wearing of a shore under the action of the waves, these and countless other manifestations can never be described in mere words. The eye must see before the mind understands and believes.

PUPILS' COLLECTIONS.

Then still another advantage is the opportunity of collecting specimens for the school and private collections. Pupils think infinitely more of specimens they themselves gathered than of great museums which some one else has filled. They will study their own and treasure them.

And it is far better to know all about a small collection than to have a vague, hazy, mysterious notion of a great one. It is far better for the pupil to know that he is actually capable of understanding a tiny bit of nature than to be haunted by the feeling that somehow all this world of things and life is not meant for his understanding.

INTEREST THE PRINCIPAL CONSIDERATION.

I believe it is wiser to give the student a taste of geology and a taste of botany and zoölogy than to limit him to the exhaustive study of just one science. Once acquiring a healthy appetite and means of satisfying that appetite, and he will go on with these keys and unlock the treasure-houses of nature for himself. We sometimes forget that we are training pupils for life's duties and life's happiness.

When I take a class in geology on a hunt for fossils, and we come across a bed, I don't insist on everlastingly calling the trilobite we may find *Phacops latifrons* or *Isotoles gigas*. We call them all trilobites. We find they were crustaceous; how they lived, in what kind of waters; and we have gotten something out of our study; but if we rolled as a sweet morsel under our tongue the *Phacops latifrons* and *Isotoles gigas*, the pupils would forget them in ten minutes, and I wouldn't blame them.

Time enough later on for elaboration; one thing at a time. It is better to know a trilobite and a brachiopod than to know two polysyllabic species of either.

NEEDLESS PRETENSIONS.

A first-class way of killing a growing desire for scientific knowledge is to feed it on good strong doses of technical terminology; the process is quick and sure. The whole trouble lies in the fact that the teacher has forgotten that he himself was once young and came by his ponderous knowledge by slow degrees. I cannot see why some teachers imagine that they have a sort

of ten-story intellect when they haven't, and when something not so wonderful would far better answer the purpose. They certainly do not impose upon the pupils, for any one with half an eye can always size up the pupil's estimate of stately pretension.

GOOD TIMES OUT-OF-DOORS.

Another object that occurs to me, the last, and by no means the least, is to have a good time in the fresh air once a week.

To put on old clothes, carry your luncheon, and, after attending faithfully to business, collecting enough specimens, just have a jolly good time, and do as you please—fish, swim, loaf, climb trees, play games, build camp-fires, and be little children again in joyous freedom. This is not only highly desirable, but absolutely necessary; because boys, and especially girls, who have not been in the habit of roughing it, get very tired stooping and working, perhaps in the hot sun, and it is very important that a nice cool spot shall be selected for luncheon, and after that let them roam according to their own sweet will.

THE BUFFALO PLAN.

We are in Buffalo; well situated for excursions, and for seventeen years there has been organized what is known as the "Buffalo Field Club," or the "Society of Natural Sciences." The club was organized by the late Charles Linden, who had charge of the department of botany and geology in the Buffalo high school. Its members are made up of present pupils of the high school and its graduates and any other person who has a leaning toward science and a love for out-door work.

In the spring and autumn there are regularly planned excursions for each Saturday, and during the winter we have semi-monthly meetings, at which a paper is read and discussed, and scientific notes and observations compared. We at times have given complete and thorough courses in geology and botany, at which the attendance was often so large as to fill every seat in a room holding over three hundred. In our geology courses we give to each student specimens in hand, three or four sometimes, like sandstone, limestone, granite, and other common but interesting rocks. The museums of the "Society of Natural Sciences" is also at our disposal.

In botany we get ready a goodly supply of peas, beans, and other common seeds in various stages of sprouting, and these, too, are passed around in the little wooden trays grocers use in doing up butter. Then we have buds, roots, sections of trees, dried specimens of plants, and even simple chemical experiments, such as oxygen and carbonic acid gas, limewater, etc., etc.

These appliances are reinforced by stereopticon slides. All this takes time? Well, I should say it does! and labor, too; but what are we living for?

We began this sort of popular lecture teaching about seven years ago. We didn't know how it would take. There used to be nothing but empty benches at some of the best meetings of the "Mother Society of Natural Sciences," and when some of the older members dropped around that first night to give us a bit of encouragement, in what seemed to them a hopeless task, they found the place packed to the doors. Some of them were, no doubt, scandalized by the simple Anglo-Saxon language which profaned those holy precincts, but that night, and every night thereafter, settled one thing; that was the fact that the people are interested in science, and that they will come if the matter can be divested of its ridiculous and befogging pretensions. And be it understood the subject in hand and the great truths of science suffered the abatement of not one jot or tittle of their nobility, their grand and their inspiring simplicity.

In the high school it is an understood thing that each pupil in the out-door sciences shall make at least six excursions. There are regularly planned field excursions, which I or my assistants take charge of. If, on account of expense or hindrance at home, the pupil cannot go with us, or stay all day, an excursion must be made somewhere by trolley—to the river, park, an open trench, or only into the back yard; but somewhere the pupil must go with notebook to observe, study, and to report. But the localities we visit are so rich, and withal usually so attractive, that, in my experience, less than one per cent failed to attend. We always secure very low rates on the railroads.

The pupils like to go and want to go. I have had graduates come again and again who affirmed that the best study they ever had was geology, and the finest times of their school year were

the Saturday excursions. You get to know your students better in the field, and as to its taking too much time, I say it pays not only the teacher ten-fold, but does a wonderful lot for the student.

I taught geology and went on excursions every Saturday, and yet had the management of a high school with over 2,000 pupils. My class-room work and the excursions were the only fun, besides my salary, that I ever got out of my work. It is time well afforded; you yourself will renew your youth, and you are inculcating a habit in your students that is healthful, pure, ennobling; you are giving them that which will make a trip to the mountains, to the seashore of infinitely more value than it ever can be to the hordes of unfortunates who kill time, lolling on hotel verandas, or who yawn on the beach. A simple walk along a country road or over a field will be a beautiful picture gallery or wonderful museum, the catalogue of which will be in the heart of your former student.

In planning our class excursions we try to arrange matters so that the botanists, geologists, and zoölogists can all go together. It is not always possible, however, to combine the classes. In any case, the schedule of excursions must be carefully planned in order to get the best results.

For geology, that is not necessary; but it is desirable to begin with examples in dynamical geology; then structure and fossils; but that is the simplest matter of all. Any locality embraces scores of interesting facts, and these the pupils are directed to observe and jot down for a future report.

Every pupil is required to make a collection of at least thirty different rocks and fossils during the term. Pupils get much more than that, but as we give only one term to geology, and that includes laboratory work on thirty-three other rocks and minerals, it is unwise to make the study a burden.

I never require a book lesson the school day following on an excursion, because I want the pupils to feel perfectly free from anxiety, to rest from any physical fatigue, and to study the collection they have made. The report is not due for several days, so we just spend the hour in talking about the excursion. It may sometimes be wise not to meet at all, since a whole day was given up already. One must always remember that every-

thing can be overdone, and that the pupil has other studies besides out-door science.

THE MANAGEMENT OF SCHOOL EXCURSIONS.

The conduct of the excursion must be understood to be in your own hands, and that you are master, and you must be obeyed without question; otherwise, parents may have a perfect right to refuse their sons and daughters to your care. Of course there will always be one or two silly persons. There will be that excruciatingly facetious chap who wears a girl's hat, and doesn't think you meant what you said when you forbade any one to cross the high railway trestle. But he finds out, and is combed down to the queen's taste in short order. On the whole, it is singular how orderly and earnest an excursion party can be.

An excursion would lose much of its value unless observations were noted, drawings made, and specimens collected and exhibited in the class-room. The pupil should handle the specimens himself, and be made to describe what he sees. Here, again, is the great danger that the teacher will tell too much. It is amazing to find how much one can draw out of pupils by simply keeping at it. Make them tell why this piece of sandstone is gray and that red; why the stream was so winding, and what formed the bar and the sand spit at its mouth.

Now, all this field work can be gotten out of secondary pupils, and as far as we are concerned in Buffalo, no one has ever questioned our right to demand it.

THE QUESTION OF EXPENSE.

Of its value, there is not a shadow of a doubt, in my mind; the results are eminently satisfactory. I believe it is practicable for any class in secondary schools to make at least six field excursions. They need not always occupy the whole day, and they can be made for less than $2.50 all told. In country schools this would be far less, and even without spending a cent.

It is surprising to find the entire absence of complaint on account of expense. The parents, no doubt, are satisfied and pleased with the account given of the trips. And should there be a pupil who cannot afford the expense, a little tact on the part of the teacher will soon arrange something satisfactory.

I believe it is satisfactory, then, to make at least six excursions

as a class each term; out-door work and observation need and must not be limited simply to spring and autumn. Individual excursions should be encouraged and collateral reading recommended for all, of which due credit should be given. There is always something to be observed at all times which has an important bearing on geography, geology, botany and zoölogy, and there is much side reading, and many beautiful tales and myths in prose and poetry, all connected with these subjects.

I cannot believe that so important a branch of science work as field study is neglected. If it is neglected, the person having the class in charge is either ignorant of the pleasure and the great profit derived from such work, or else not in sympathy with the work. For who can look about him, see all the phenomena and facts of nature, all their deep meaning, feel all the profound emotion which stirs the deepest and purest sensations in the human breast and not rejoice in the fact that it his great privilege to be a teacher, and to lead young minds to a fuller realization of the works of God.—*The School Journal.*

SOME EDUCATIONAL REASONS FOR OBSERVATIONAL TEACHING IN ELEMENTARY ASTRONOMY.

By George W. Myers.

Most teachers who have seriously attempted to define for themselves the aims of education admit that knowledge, as commonly understood, is at best but a subsidiary *aim.* This relegates the text-book to a secondary place in teaching. But when the truth of the first statement begins to dawn upon the teacher he is in danger of underestimating knowledge as a *means* of education. The text, therefore, has a legitimate place, even though secondary. No one needs to bear these two facts more clearly and continually in mind than does the high school science teacher. Knowledge as *means* is sound pedagogy, knowledge as end is quite another proposition.

It is indeed well for the science teacher both in the secondary

and in the higher schools at times to restate the aims of teaching in terms of his own science. Too frequently the teacher of the physical sciences is so engrossed with the beauties and revelations of his subject as to fail almost, if not altogether, in this important duty. Even teachers who become text-book writers are guilty, it would seem, of gross delinquency in this respect, when they make their books mere compendiums of their special sciences, or outline-courses for popular reading in these subjects. Prefatory statements of writers of texts in the mathematical sciences to the effect that the purpose of the writer has been to eliminate all demands for the mathematics would seem to argue the author into this same category of delinquents, if indeed it does not impugn his motive as a man of science. It is doubtful whether any physical science can roll up a larger percentage of teachers who fail—unintentionally, of course, but none the less fail—practically to recognize the importance of inquiring into the relative value of various possible methods of presenting truth to beginners than can astronomy. It is believed that this deplorable state of things astronomical, perhaps nowhere so conspicuously and perniciously present as in our high schools, is both a cause and an effect of the general apathy, now happily passing, felt toward the educative value of this noble science.

In the March number of SCHOOL SCIENCE the writer briefly and somewhat crudely presented the reasons for the prevalence of this feeling. In this paper he will briefly state some of the educational principles which have wrought significant changes in school curricula by the introduction into them of physics, chemistry, zoölogy, etc., and which seem to demand a restudy, if not a reconstruction, of the relations of astronomy to the educational series.

Most teachers will agree that education results from self-effort made in accordance with law, and *from this alone.* The pupil makes an effort to remember, and in some mysterious way his memory becomes more vigorous; he makes an effort to determine and his will is thereby strengthened; he puts forth an effort to think, and his power to think is enhanced. This means we can train a pupil to do a thing only through his *own* efforts to do it. No pupil can attain to the ends of scientific study save

through his own efforts to do so. The teacher can be of service in the way of removing obstacles which dissipate his energies and of indicating guiding principles.

This, however, implies a knowledge, at least on the teacher's part, of the purpose of scientific study. It would be easy to prove, though space cannot be taken for it, that the end of such study is to train the student's mind into the mental habits of the investigator. This requires the teaching of enough knowledge for the student's mind to work upon; but makes mental activity toward a definite goal the important consideration to the teacher. It does not demand a bookful of facts unrelated to the pupil. This cultivates the verbal memory only, and that is the one faculty which does not need cultivating. In the next place, let us seek to ascertain what this definite goal must be.

This necessitates the inquiry as to how the trained scientist deals with his materials in the progress of investigation. This is true because so far as the beginnings are concerned the aim of the prospective scientist and of the general student are identical. In other words, let us ask, how does the investigator proceed in the collation and elaboration of his materials and in his reasoning upon them? This is substantially the same as to ask, what is the method of science? This question has been answered so recently and so well by one of the most eminent scientists of our country that the writer ventures to quote the answer here:

"The accumulation of pertinent observations, the classification and generalization of them, the framing of hypotheses from the materials thus obtained, deduction from these hypotheses and comparison of the products of these deductions in every way possible with new facts until substantial certainty is reached—these are the general steps of the method of physical science."*

A little further on the writer from whom the above is quoted, states that a flash of insight may permit an expert to see quickly whither an investigation is tending and thereby enable him to abridge one or more of the steps mentioned, but adds that if an inquirer omit or obscure *a sure starting point* and *a rigid verification* he thereby proves that he is not even a scientific man at all.

*S. A. Forbes, "The Method of Science," *Public School Publishing Co.*

Without observation and classification there can be no science at all.

If, then, we grant that the study of any physical science should predispose the student's mind to this inductive-deductive method of truth-seeking, how can we teachers of astronomy fail to recognize that when we are eliminating entirely, or even subordinating, observational and experimental work with our classes and depending entirely upon the text-book that we are doing just about as good as no teaching at all?

The series of experimental exercises which the writer promised in the March number, and which are intended to bring within easy access of all readers of SCHOOL SCIENCE, who are desirous of putting high school astronomy on a modern basis, the means of doing so, will be begun in the first issue in the fall.

INFLUENCE OF EXPECTATION IN QUANTITATIVE WORK.

BY N. A. HARVEY.

Department of Natural Science, Chicago Normal School.

In the March number of SCHOOL SCIENCE is an article upon "Quantitative Experiments in Chemistry for High Schools," which contains an excellent estimate of the advantages to be gained from quantitative work in chemistry. In illustrating the possibilities of quantitative work, the writer gives some examples of accurate results obtained by large classes. The examples are certainly very remarkable, and the difference between the extreme results reported is very small. Certainly such work must be productive of the greatest benefit to students.

But one circumstance was omitted upon which will depend, in a very great measure, our estimate of the benefit the student derives from such work. Did the students know before completing their work how much they ought to get, or just about what the answer should be? Any one who has studied the influence of expectation upon judgment knows how much it modifies a conclusion. If, in a quantitative determination, a student knows what result he ought to get, he will get that result almost in spite of himself. It is not necessarily something dishonest, but it is

unavoidable. This is true in quantitative chemistry, it is true in qualitative chemistry, it is true in physics, it is true in biology.

The present writer used for some years a very excellent laboratory manual of zoölogy, containing laboratory directions for the study of a perch. It happened to be more convenient to furnish sunfish for class use, which are very similar fish. The laboratory directions indicated that teeth would be found on the palatine bones. Ordinarily about two-thirds of the class would find teeth on those bones, when in fact the sunfish, which was the one they were studying, has no teeth in that situation.

In quantitative work in chemistry, the pupil is likely to obtain a knowledge of the correct answer to a particular problem. He may get it from the teacher, from a text-book, from reference books, or from the note-books of a previous class. If pupils do have such information it takes away a large part, I should say the larger part, of the value accredited to accurate results.

Equally vicious results are met with in biological subjects. When I go into a laboratory and see note-books containing drawings of the objects that the pupils are studying that look exceedingly like pictures in books with which I am familiar, I at once enter an indictment containing the charge of false pretenses. When I see hung around the walls finely executed charts labeled with a pupil's name, and professedly drawn by the pupil from the object, but which are exact reproductions of figures in standard books, I feel that I am in an art room instead of a laboratory, or that there is need of conversion on the part of some one. Of course the pupil can find all the mouthparts of a crawfish if he knows what they are beforehand, what they look like, and the order in which they come, and especially if he works with a picture or mounted specimen before him. That is not the question. Can he determine for himself the number, kind and arrangement of the mouthparts from the crawfish alone, without other assistance? That will constitute a measure of his power, and a promise of future success.

It is particularly the province of scientific subjects to make the student independent, self-reliant, and capable of seeing things as they are, and not merely as he thinks they ought to be, or as some one else says that they should be. If science fails to do this

it fails to accomplish a large part of the purpose for which it is introduced into the curriculum.

It is the old story of the pony in Latin and the key in arithmetic and algebra. Teachers of Latin and mathematics have got beyond the stage of the pony and the key. I do not say that teachers of science have not, but some things that I have seen leads me to suspect that this touches upon the weakest spot in the science teaching of even our best high schools.

The only method I know to avoid the obtaining of information in what I consider an illegitimate way, is to start right with a class and cultivate the proper spirit toward the work. I know that the proper spirit can be cultivated so that pupils will not seek information about their experiment except from the experiment itself, and that the effect upon the character and intellect of the pupil is vastly superior to that which results from the usual method.

THE MODERN PRESENTATION OF BOTANY.

By A. M. Ferguson.
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Botanists are interested in the advancement of science, whether it be by encouraging investigations in new fields or by the diffusion of knowledge already accumulated. The latter may be secured by popular lectures, magazine articles, etc., but the most thorough, useful and substantial advancement is begun in our public schools. The school science teaching, then, merits our earnest attention for this reason. In advocating higher standards of science it may be said for the non-scientific that it is not for science's sake, but for the school's sake. No science is an end in itself, and the advancement of science is not the question of greatest moment. "Instruction in any subject should develop a capacity for thought and conduct and no scientist wishes to shirk his share of responsibility in training for good behavior and good citizenship. If he has not this faith his right to spend his time in the advancement of science becomes a matter of question. * * * From the standpoint of its effect upon character and

upon citizenship the investigator has a direct interest in the nature of the instruction given to boys and girls whose education ends in the public schools. His greater knowledge imposes upon him the duty of helping to shape this instruction aright." This has been recognized and heeded by several eminent American botanists in the last few years. More than a half-dozen elementary text-books have been put upon the market in so short a period, representing so many schemes of presenting botanical science to the beginner. In passing upon the schemes proposed we should keep clearly in mind the science and the educational value of the science *per se*.

Botany has much in its favor as a distinctly cultural study. It also has that other value which all school studies should have, to wit: practical value when applied to every-day affairs, or, as the Englishman says, "getting along." Whatever may be said of the "scientific method" in the school-room and in business, may be said of botany. It is not an easy task to discuss a scheme of presenting the elements of a science without repeating much that may be said for the sciences in general, especially the biological sciences.

The educational value of a course in botany will depend as much upon the spirit and individuality of the teacher as upon the method of presentation. While the time allowable for such courses is necessarily limited they should be coördinate with the other sciences, and the technical knowledge, so far as it enters into the educational process, should be exact, correct and satisfactory to the specialist. In such a course it is neither how much nor how well scientific knowledge, *per se*, has been imparted to the student, but how much stern but agreeable mental training has the study afforded. It should develop in proper coördination the three most important mental faculties—observation, comparison and deduction.

Botany does not mean the "analysis and naming of flowers" alone, nor does it consist in pressing a few fragmentary specimens in an old geography and calling it "an herbarium." The ultimate question in botanical science is, "How came plants to be as they are?" and takes in not only the genesis and evolution of the plant world, but more especially the relation of vegetation

to things in general. "Botany," says Professor Goodale, "is the science which attempts to answer every reasonable question about plants"—*i. e.*, how they grow and are grown, when and what they came from, their habits and peculiarities and the relation they bear to the general economy of nature. But you cannot treat the science comprehensively in an elementary presentation. The question, then, that has received such various answers in the text-books referred to is this: "What kind or part of botany will give the best returns for the time and energy expended," or, as Professor Ganong puts it, "What phase of botany best develop the scientific instincts; and what knowledge of plants is educationally most useful to the average student?" All the answers have been synthetic; that is, the courses in botany are planned to do for the students of the vegetable world just what physiography is doing for the student of the land,—to demonstrate the factors determining its present construction. The factors are more complex for the vegetable world and cannot be answered in an elementary course, yet the science and the instruction have this trend. How much broader is this than the "morphology and analysis" so much in vogue not many years back?

In conclusion, I wish to commend to every teacher Professor Ganong's "The Teaching Botanist." In addition to a quite suggestive discussion of botanical pedagogics and valuable "shop" talks, an outline is given for a comprehensive course in botany admirably suited to certain conditions. Where time and laboratory equipment allow, a different order of treatment seems to be advisable.

The Lavoisier Medal.—The French Academy of Sciences has voted to distribute annually a gold medal in memory of Lavoisier. M. Paulin Tasset is preparing the die for the medal and has taken as a model the well-known medallion by the sculptor, David d'Angers. The name "Laurent Lavoisier" will be under the profile, and on the back will be inscribed the words, "Institut de France, Académie des Sciences, Medaille Lavoisier." The project is in the hands of M. Berthelot.

A HIGH-SCHOOL LIBRARY FOR PHYSICS.

By H. N. Chute.

No one questions the truth of the proposition—every high school should possess a carefully selected library for the use of its pupils. That this is true is shown by the fact that the majority of such schools are today equipped with libraries of reference books, more or less complete, and are adding to them as ways and means are provided. In most cases our schools are under the management of men of classical training and tastes and as a consequence the books that have been selected for the libraries have been very largely, if not wholly, in the line of history and literature. Within the last few years the sciences have been demanding a place in the educational curriculum with a persistence and a force of argument that would brook no denial. They have come asserting their ability to give a mental training equal in every respect to that produced by the time-honored classics. Nor have their claims passed unheeded, notwithstanding the oft repeated assertion of their opponents that "they are without culture value." Against much opposition the sciences have made for themselves a place in the curriculum of our secondary schools and are today demanding equal rights with literature, language and mathematics. The advent of the Laboratory Method in science instruction has wrought a wonderful revolution in the opinions of educators as to their educational value, so much so that some have come to believe that it is only through the test tube, the caliper and the balance that real knowledge can be gained. Under the classical régime in our schools, we did little else but study books and worship their authors. The Aristotelian Method reigned supreme; books were our authorities for everything, nothing was tested, nothing tried. Within recent years the Baconian Method has rushed to the front with such a din and persistent shouting that many of us have quite lost our heads, or at least there is danger of it, and we proclaim on every possible occasion that "there is no source of knowledge but experiment," and that "by its means alone can we learn anything new or cer-

tain." It is the purpose of this discussion to call in question this new dictum and to maintain another proposition, to wit, that books are as much the tools of the student of physics as are his calipers, his resistance box, or his spectrometer; that if he is to know much of its laws, the history of its development and its wonderful possibilities, he must look beyond his own meager investigation; that if he would have a well rounded-out knowledge of the physical world, he must combine library and laboratory.

The student of physics must learn how to use books, how to search them for information on the various questions that come up in his studies, just as he learns how to observe, how to experiment, how to discuss and analyze data obtained and extract from them their hidden meaning. It is a great gain to learn that information on this electrical fact or on that optical phenomenon can be gleaned from many books, where each writer has expressed it in his own peculiar way; this one bringing out one shade of meaning and that one another, each supplementing the other and rounding out one's knowledge to greater fullness and clearness.

It has been said that the great end of all education is to make people able to educate themselves. If this be true, and true it undoubtedly is, that school will be most helpful to that end whose library is well filled with carefully chosen books covering all departments of learning, whose students are trained in the wise and proper use of these books, having studied them much as the skilled mechanic does his tool chest, to the end that he may know where to find things when needed, and how to use them when found to the greatest advantage. For after all, does not the education that has real value consist in great part of having learned the places where information can be obtained? Does the astronomer remember his intricate formulæ, the chemist his analytical tables, and the physicist the outcome of every experiment which has been tried? Each is content if he but know where such information can be found when needed, provided his training has been such as to enable him to apply it correctly to the work in hand.

It would seem that of all students, the one of physics most

of all needs books. The beginner should have them to add flesh, blood and color to the dry bones of the school text book; to add interest to the subject by bringing his mind more fully in contact with the wonderful store-house of useful and attractive facts lying dormant in these treasure houses. He should read the biographies of some of the great scientific worthies. No boy can read the life of the immortal Faraday without feeling a healthy moral glow within his very soul and without experiencing a strong desire to imitate in some small way that sweetest, greatest and withal most modest of modern thinkers. He will also find it very helpful to read a little of the history of physics. The difficulties that the students of today encounter in the study of this subject are the same ones with which the master minds have restled; and it will often prove true that the best way for the student to meet them is the one discovered by the thinkers and workers of many years ago. It is an encouragement for the student to know that what he finds "hard to learn" is what has perplexed learners ever since the days of Thales, and it will be of great value to him to know of the patience and persistence of these seekers after truth and knowledge, of the self-denial and devotion exercised in their pursuit of facts and truths which they had reason to believe existed, but were unrevealed, of their many failures and final success in reaching the goal of their ambitions. It gives him courage to "up and at it," for he feels that his failures are not necessarily due to his native dullness, but are inherent in the subject itself.

Not only will the history of physics be helpful in surmounting difficulties, but its study will add interest and zest to the work. No boy or girl can read the story of Guericke and his quaint air-pump, the amusing episode of Cunaeus and his Leyden jar, the controversy between Galileo and his Aristotelian opponents, the discovery of atmospheric pressure by Torricelli and a hundred other interesting stories that sparkle throughout the pages of science, without having his scientific appetite whetted for further reading and for further investigation, to say nothing of the help to memory, and to the reasoning faculties in the better understanding of the principles laid down in the text books on the subject.

To make the most of this reference library for physics, the teacher must know its contents as thoroughly as he knows his laboratory, to the end that he may refer his pupils to the proper sources of information and guide them intelligently in their reading. He should have read these books with this end in view. And in doing so he will find himself unexpectedly rewarded in the greater facility he has acquired in explaining difficulties, in the ability gained to approach them from various sides. Every teacher knows that an explanation that may be clear to one student is not always equally clear to another, and that it is necessary to resort to many expedients and devices to make things clear to all.

As a nucleus for a Library for Physics I would suggest the following books, those marked with an asterisk being given the preference:

BIOGRAPHY:

*MICHAEL FARADAY. His Life and Work. *S. P. Thompson.* The Macmillan Co.

*PIONEERS OF SCIENCE. *O. J. Lodge.* The Macmillan Co.

HUMPHREY DAVY, Poet and Philosopher. *T. E. Thorpe.* The Macmillan Co.

JAS. CLERK MAXWELL AND MODERN PHYSICS. *R. T. Glazebrook.* The Macmillan Co.

HISTORY:

*A HISTORY OF PHYSICS. *F. Cajori.* The Macmillan Co.

*A POPULAR HISTORY OF SCIENCE. *Robt. Routledge.* George Routledge & Sons.

A SHORT HISTORY OF SCIENCE. *Arabella B. Buckley.* Appleton & Co.

HISTORY OF THE INDUCTIVE SCIENCES. *W. Whewell.* Appleton & Co.

GENERAL PHYSICS:

*RECENT ADVANCES IN PHYSICAL SCIENCE. *P. G. Tait.* The Macmillan Co.

*CONSERVATION OF ENERGY. *Balfour Stewart.* Appleton & Co.

*NATURAL PHILOSOPHY. *A. P. Deschanel.* Appleton & Co.

GENERAL PHYSICS. *Hastings* and *Beach.* Ginn & Co.

PRINCIPLES OF PHYSICS. *Alfred Daniell.* The Macmillan Co.

*UNIVERSITY PHYSICS. *H. S. Carhart.* Allyn & Bacon.

MECHANICS:

*ELEMENTARY MECHANICS. *O. J. Lodge.* W. & R. Chambers.

*MECHANICS AND HYDROSTATICS. *R. T. Glazebrook.* The Cambridge University Press.

SCIENCE OF MECHANICS. *E. Mach.* The Open Court Publishing Co.

MECHANICS. *R. S. Ball.* Holt & Co.

DYNAMICS AND HYDROSTATICS. *A. Pinkerton.* Blackie & Son.

HEAT:

*Elementary Treatise on Heat. *Madan.* Longmans, Green & Co.
*Theory of Heat. *J. C. Maxwell.* Longmans, Green & Co.
*Theory of Heat. *Thos. Preston.* The Macmillan Co.
*Heat a Mode of Motion. *Tyndall.* Appleton & Co.
Growth of the Steam Engine. *R. H. Thurston.* Appleton & Co.

ELECTRICITY AND MAGNETISM:

*Electricity and Magnetism. *S. P. Thompson.* The Macmillan Co.
*Modern Views of Electricity. *O. J. Lodge.* The Macmillan Co.
*Primary Batteries. *H. S. Carhart.* Allyn & Bacon.
Dynamo-Electric Machinery. *S. P. Thompson.* E. & F. W. Spon.
Arithmetic of Electricity. *T. O'Connor Sloane.* Munn & Co.
Electrical Rules and Tables. *Monroe* and *Jamcson.* Chas. Griffin & Co.

SOUND:

*Sound and Music. *J. A. Zahm.* A. C. McClurg & Co.
*Sound. *John Tyndall.* Appleton & Co.
Theory of Sound. *P. Blaserna.* Appleton & Co.
Sound. *Poynting and Thomson.* Chas. Griffin & Co.
Sound. *A. M. Mayer.* Appleton & Co.

LIGHT:

*Theory of Light. *Thos. Preston.* The Macmillan Co.
Nature of Light. *E. Lommel.* Appleton & Co.
*Polarization of Light. *W. Spottiswoode.* The Macmillan Co.
*Light. *Lewis Wright.* The Macmillan Co.
Spectrum Analysis. *H. E. Roscoe.* The Macmillan Co.

MISCELLANEOUS:

*Soap Bubbles. *C. V. Boys.* E. & J. B. Young & Co.
*Experimental Science. *Geo. M. Hopkins.* Munn & Co.
*Time and Tide. *R. S. Ball.* E. & J. B. Young & Co.
Lectures on Scientific Subjects. *J. F. W. Herschel.* George Routledge & Sons.
Fairy Land of Science. *Arabella B. Buckley.* Appleton & Co.
*Physical Tables. *Thomas Gray.* Smithsonian Institution.
Common Sense of the Exact Sciences. *W. K. Clifford.* Appleton & Co.
*Properties of Matter. *P. G. Tait.* A. & C. Black.
*Matter and Motion. *J. C. Maxwell.* Van Nostrand & Co.
Flame, Electricity and the Camera. *Geo. Iles.* Doubleday & McClure Co.

ZOÖLOGY IN SECONDARY SCHOOLS.

BY MAURICE A. BIGELOW.
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(*Concluded from page 72.*)

The college and secondary courses under such a system would be supplementary with no repetition, and in the end those students who take both college and secondary courses in zoölogy may have a broad view of animal structure, function and life. There can be little doubt that the course in natural history is valuable in preparation for the more advanced work in the college, but it may well be doubted whether such a course is altogether the best for secondary work when considered from the standpoint of liberal education. In the omission of all reference to the general facts of internal structure and functions, has not the reaction from the purely morphological course been too extreme?

In secondary work the important physiological side of zoölogy has received but little attention, as compared with that given to natural history and morphology. In the types of elementary courses which have been discussed, there is often some mention of comparative physiology, or some observational work on responses to external stimuli; but, on the whole, physiology can hardly be considered as one of the characteristic features in the usual examples of either of the two types of courses. The fundamental physiological relations of the internal machine of the animal body have been neglected almost universally, but they should be as characteristic as any other feature of an elementary course.

The importance of interpreting the activities of the human body from the comparative standpoint seems sufficient reason for advocating the consideration of the fundamental principles of physiological action in connection with the study of elementary zoölogy. Experience has convinced the writer that there is no more profitable study for secondary pupils than the physiological side of animals. No other phase of zoölogical study arouses a deeper interest and appreciation or is more spontaneously applied by the pupils in connection with study of their own life activities. It is scarcely necessary to offer a stronger reason for including such study in an elementary course.

Summarizing the review of the ordinary types of courses in elementary zoölogy, we must recognize that there are important features in both the morphological and the natural history courses, but when standing alone each is extreme. Each has fundamental facts and ideas which are of interest in liberal education, and also in each there are numerous details which have only special or technical value. From this follows the suggestion that the essential and valuable features of the two courses may be selected and incorporated into one. But this is not sufficient, for it has been pointed out that the very important physiological side of zoölogy deserves attention, which neither of the ordinary courses gives. The course, then, which will meet the demands of liberal education should be a study of animals from the combined aspects of the fundamentals of morphology, physiology and natural history. This statement must not be misinterpreted. To a naturalist each of the three fields is much too wide even for a lifelong study, but it must be kept in mind that the problem in secondary work is to give the pupils the most valuable ideas of animals, and the widest view of animal life. The demand of liberal education is for a broad attitude of mind toward animals, and good general ideas of the fundamentals of zoölogy. The vast masses of facts of detail which interest the naturalist must be reserved for special study by those who have time and special reasons for advanced study of the science.

Among the minor problems involved in arranging a course combining the essentials of the various phases of zoölogy, the first and most difficult one is concerned with the inclusion of physiological work in the course in elementary zoölogy. By physiological the reference here is directly to the essential processes in the general metabolism of the animal body, and the term is not limited to the mere work of observing a few movements and responses to stimuli which constitutes the great part of the so-called physiological study in many elementary courses. The study of fundamental physiological processes obviously admits of very little practical work in a direct line, and the facts must be presented by text-book and teacher. But the morphological basis for such can be strictly practical, and a logical presentation should lead the pupils from observed facts to conclusions, so that the

discussion of the subject of general physiology of animals may be of far more value than a mere didactic exercise.

The usual objection to physiological work in secondary schools is that the subject cannot be presented by a strictly laboratory method. But how much physiology does the advanced student get directly from his own laboratory studies, as compared with what he accepts on the authority of teacher and books? In how many colleges is the laboratory method *strictly* and *exclusively* applied in biological teaching? The evident answer to these questions shows how weak is the argument that only strictly practical work should be included in elementary zoölogy in secondary schools.

In combining physiology with the morphological work of the course in zoölogy, it is important that the two phases of study be closely related throughout the course. The few text-books and teachers' outlines which merely suggest a tendency toward a union of the two phases of zoölogical study seem to show that in general the attempt is to teach physiological ideas in the form of abstract generalizations with little of concrete application to particular animals which are studied morphologically. Sometimes these generalized principles of physiology are introduced before the pupils have progressed far in the practical study of animal structure, but more often after the completion of a purely morphological course. Such a method of presenting the principles apart from concrete application is open to serious objection. In the light of experience it may well be doubted whether such presentation gives secondary pupils a clear conception of general life-activities. A physiological principle may be formulated in a generalized way, and as such may be memorized by the pupils; but that they do not grasp the ideas involved is shown by the fact that they usually fail in application when concrete cases are placed before them. Every zoölogist knows in personal experience how indefinite and unsatisfactory are the ideas gained from reading generalizations if he cannot easily recall and connect them with the specific underlying facts. In order to appreciate the attitude of the elementary pupil, it is only necessary to recognize the fact that even at the close of a half-year course the pupil has not the definite remembrance of the details of the structure which are neces-

sary for concrete illustration and application of the principles of physiology. In order to give the clearest possible conception of physiological principles it is essential that structures and functions should be studied in their natural relations. The principles of physiology should be introduced with the first animal which is studied morphologically, and each principle as introduced should receive concrete application. The study can easily and quickly be made comparative as successive types of animals are taken up, and finally such specific and comparative studies may be made to lead to a direct application of the principles of comparative physiology to the activities of the human body.

Another minor but important problem which demands consideration is the much discussed question regarding the value of unicellular versus multicellular animals as types for the introductory study. Shall a course in elementary zoölogy be synthetical, beginning with unicellular animals and then progressing toward the more and more complex forms, or shall the study be analytical and, beginning with a complex multicellular animal, lead down the scale of structural and functional complexity to the simplest forms? The first named order is the one usually followed, and it is defended chiefly on the ground that it corresponds with the logical order in the development of complexity in the animal series. However much weight this may have in college work, it is doubtful whether the generalizations involved in considering animal structure and function synthetically are grasped by immature beginners in secondary schools. Moreover, an appreciation of the relations underlying the great idea of organic evolution does not necessarily depend upon a study of animals taken in the order of increasing complexity. It appears then that the argument for logical order must be regarded as insufficient.

The difficulties involved in an attempt to grasp the meaning of the structure of a protozoön are greatly complicated by the compound microscope. By use of the microscope is not meant mere mechanical manipulation, but especially accurate interpretation—a far more difficult thing for most beginners. Very many teachers consider this alone sufficient reason for *not* beginning the course of study with a microscopic form, for if the intro-

ductory type is a multicellular form of considerable size, the use of the microscope can be learned gradually in connection with the gross examination.

The advantages of beginning the study of structure with an animal about which the pupil knows something, or at least can learn with the aid of no more uncommon apparatus than the eyes, were well stated by Huxley many years ago after he had learned by experience the great disadvantages connected with beginning zoölogical study with a microscopical animal. Many teachers in colleges have since expressed agreement with this opinion of Huxley. As applied to elementary zoölogy in secondary schools where the pupils are undeveloped, the arguments advanced by Huxley are of greater weight than when applied to college work. Pupils encounter few serious difficulties in an introductory study of the important points of structure in a complex animal. The supposed difficulties arise largely when detailed study is attempted. The general relations and the *essential* structure of organs are in the very beginning readily determined and comprehended by very young pupils.

The same arguments hold good from the physiological point of view. Every pupil knows something about the functions of his own body, and it is easy to grasp the fundamental principles of physiology when concretely applied to organs of an animal in which there is considerable physiological division of labor. It is evident that this must be a decided gain when compared with beginning physiology with a unicellular animal where all functions must be thought of abstractly in connection with a single cell. Beginning with the physiology of a multicellular animal, and considering a series of simpler forms which lead down the scale in division of labor, the pupils can understand every step of the way, and in the end will have a clearer idea of the functions of both one- and many-celled forms in their relation to the great principle of physiological division of labor.

The conclusion must be that so far as the work of secondary schools is concerned there is very little to be said in favor of introducing the course in elementary zoölogy by the study of a unicellular animal, while there is much in favor of beginning with the multicellular form. The simplest animals appear to be, after

all, the most complex from the young beginner's standpoint. More than this, almost everything which is supposed to argue for a logical and synthetical order of study depends upon generalizations which are not appreciated by the average secondary pupil. The experience of large numbers of teachers seems to support strongly such conclusions.

In preceding paragraphs it has been advocated that elementary zoölogy should include the most important facts and ideas of general anatomy, natural history, and the essentials of physiology. It has also been urged that physiological study should be intimately associated with morphological study from the very beginning of the course. Finally, reasons have been given for regarding multicellular animals as most favorable for introductory work which is to involve any of the above aspects of zoölogy.

Depending directly upon the foregoing conclusions, the central idea of the course in elementary zoölogy which is outlined in this paper* is that of an introductory study of a complex animal examined from the several view-points of zoölogy. Such a study includes the most important facts of anatomy, histology, embryology, classification in connection with the near allies of the introductory type, distribution and ecology, general fundamental principles of physiology, habits of life, and life history. Again it may be necessary to remind the reader that this is not to be misunderstood as meaning that any one of these phases of study should go far into details. The question—What is essential for liberal education?—should be strictly applied in eliminating all that has no good reason for inclusion in the course. The writer's interpretation of what may be considered valuable in this connection will be best represented by a detailed outline of such an introductory study of one animal, and this is given in the outline of the course.*

This method of introducing the study of zoölogy by a broad biological study of a single animal has long been favorably received in college work. It is unnecessary to show here that the important facts of animal structure and function can be well presented and illustrated by study of a single animal. Huxley's classical work on the crayfish, as an introduction to the study of

*In *Teachers' College Record.*

zoölogy, gives sufficient defense to this method; and Sedgwick and Wilson have successfully applied the same idea to the earthworm. These two books have suggested the line of work which is here advocated for elementary zoölogy. Both the work of Huxley and that of Sedgwick and Wilson are far too advanced and technical for elementary pupils, but it will appear in the general plan of the outline that these books have contributed many suggestions.

Such introductory study as has been suggested can be completed within the first five weeks of a half-year course, leaving eleven or twelve weeks in which to have a broad survey of the animal kingdom. This will be criticised on the ground that it gives too much attention to a single animal; but it will appear in the outline that most of this time is devoted to zoölogical principles capable of wide application, and which are illustrated by the careful study of a single animal. After pupils once grasp these principles, application to animals which are studied later is easily and quickly made. This method of introducing the study is designed to give pupils general ideas of the structure and activities of one animal which will aid in appreciating and interpreting any other animal. It is also intended to give intensive study of the fundamental principles of anatomy and physiology, and thus lay a foundation for a deeper acquaintance with many other animals representing important groups. Accepting the view of those naturalists who consider studies in natural history very important in liberal education, the aim is to prepare for them by including in the introductory work many of the most important topics from the other phases of zoölogy, so as to give a broader view of animals and their life than natural history alone can give. In short, the general aim is to lay a foundation which will make later study of animals, from whatever standpoint, more interesting and more intelligible, because there is included in the foundation work those great principles of animal structure and function which are of wide interest and application.

The writer is convinced that the broad view of a single animal and of some of the general principles of zoölogy, gained from the introductory study, exert a marked influence on all subsequent study of animals. Pupils with such preliminary training may be

required later to study some animals from a limited point of view, for example, natural history or morphology, but their general ideas of one animal from the various points of view lead them to think of all animals as presenting illustrations of the various aspects of zoölogy. The pupils, as a rule, are eager to study every animal brought into the course as thoroughly as the introductory type was studied—that is, from the various aspects of zoölogy. Although time will not allow such extensive study of more than one form, there is great value in such an attitude of mind with its broad outlook and interest in the various phases of animal life. This fact is mentioned here partly for the purpose of showing that interest is not lost by extended introductory work, as some critics have already urged on *a priori* grounds. Experience indicates that there is a gain rather than a loss in interest.

In conclusion it is claimed that upon a broad introductory study of one multicellular animal it is possible to base a course which combines the most valuable features of the various courses usually presented in secondary schools, and that it is possible at the same time to give as good training in scientific observing and thinking as can be done with any other course. Moreover, such a course gives a view of animals and animal life which is broader and more valuable from the standpoint of liberal education than that given by the ordinary courses which are limited to the viewpoints of either natural history or morphology. This claim is based upon the fact that such a course includes the fundamental principles of physiology in the natural relations with morphology and natural history, the importance of which relation has been discussed elsewhere.

It is not claimed that pupils who follow such a course know much about the details of comparative anatomy in a series of animals, or understand the intricacies of physiological processes, or that they store up a mass of facts from natural history; but from the standpoint of liberal secondary education stores of facts are not needed so much as broad general ideas, and an acquaintance with and interest in animals and their life.

SOME EXPERIENCES IN EQUIPPING THE LABORATORY.

By W. E. Bowers.
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While the more elaborate and expensive pieces of apparatus must always be made by skilled specialists, and supplied by the dealer in apparatus, wonders can be accomplished in the way of "home-made" apparatus by the enthusiastic teacher and the ingenious pupil. But these rude devices and fantastic make-shifts are fast giving way to apparatus that is substantial, durable and accurate, and that requires the application of skilled labor. It is the purpose of this paper to suggest a means of securing apparatus of this character at a comparatively small outlay, and to make a modest plea for the policy the writer has found thoroughly successful during the past three years.

While there is everywhere a gratifying tendency to add to the laboratory equipment, too many schools, especially small schools, spend their money for a few pieces of expensive factory-made apparatus, and then worry along with one micrometer and one vernier caliper, one balance, two pneumatic troughs, and three ring stands, in a laboratory where a dozen or half-dozen of each is necessary for convenient work; or they put the money into illustrative apparatus, and do without many things necessary for individual, especially quantitative work. It is, however, the conviction of the writer that, with the exception of chemicals (which may be bought through the drug store), rubber goods, glassware, and the elaborate pieces of apparatus, the laboratory may be well equipped, and very little money sent outside the city limits.

The objection may at once be raised that there is no one to do this kind of work; yet this objection usually soon disappears upon earnest and enterprising inquiry. Few towns large enough to have a high school, are without a gun shop, a bicycle shop, or a foundry, where some workman may be found who is able and willing to do all kinds of metal work, if the design is furnished by the teacher. Often this workman is a skilled machinist; occa-

sionally he proves to be an immigrant from Europe, where he has had training in the very work required. Not infrequently he is a graduate of the local high school, or a college student, well versed in science, able not only to make, but also to design, apparatus, easy to interest in the work of the high school, and glad to be of service to the teacher and the school.

Such workmen can furnish, for practice in measurement, hardened steel rods, stamped and numbered, and turned so true that they will bear a micrometer test in any dimension, at a few cents each. An oxyhydrogen blowpipe, made after the drawing given in most texts, will cost less than a dollar. If desirable, it may be made so as to be taken apart to show the construction. Bunsen burners can be had for about the same price, or even less; and five or six dollars will get a dozen ring stands, each with a 20-inch rod and three or four welded rings, enameled throughout.

The best bargains and the best apparatus are in specific gravity balances. Only a faithful and a first-class workman can be trusted with the difficult task of making, adjusting and balancing so delicate a piece of apparatus. The writer has had three sets made at prices ranging from $8 to $18 for half dozen lots. Although the balances of the first lot were too small and too sensitive for the best results (easily sensitive to the graphite used in writing name and address), they were fairly satisfactory, and those of the last lot are highly so (experience has improved the design).

Each has a cast-iron base of neat design, and standard of small bicycle tubing (steel, 12 inches high), both enameled. The sliding telescope rod is of cold-drawn steel, the block for the bearings is sawed and drilled from steel bar and hardened; the 10-inch beam, knife-edges, pivot bearings, pointer, scale and beam arrester are likewise of hardened steel. These parts are well finished and have a polish equal to that of a good grade of shears. The pans are of spun brass, suspended on spring brass wire, of two heights, with hooks. They are bronzed and look fairly well; the *appearance* of the pans is the only particular in which they do not excel factory-made balances of medium quality.

These balances were made in the gun shop in this place and

are strong, durable, sensitive to one centigram, and equal in utility to the factory-made balances listed at much higher prices. By actual test they compare without discredit, at least while new, with certain balances which were listed at $7, $8 and $16 each.

The same workman could, if desired, make compasses, dividers, simple calipers, pendulums, models of pulleys, ring and ball apparatus, siren disc, and many other similar instruments, even a whirling table, screw press, hydraulic press, and model of steam-engine—all at reasonable prices. Of course, this policy may be carried too far; most electrical apparatus, sets of metric weights, etc., are best purchased from a dealer.

Several arguments may be urged in favor of this policy. Strange as it may seem, quality of apparatus is an object but in few cases; economy of expenditure is the main thing to be gained. Then, too, an order of this kind is always a patronage of home industry, a reminder that the high school is not a dead weight on the community, and it always tends to attract the more cordial support of public-spirited citizens, as well as of the business men, workmen and school officers.

In a series of articles to follow, the writer will give working drawings and specifications for the construction of a number of pieces of apparatus that his experience has shown can be made satisfactorily by any skilled mechanic.

WHAT CAN BE DONE WITH A SUNBEAM.

By A. E. Dolbear.

Professor of Physics, Tufts College.

Everybody knows of the magic lantern and its possibilities in a school-room, but many do not know what can be done with a sunbeam and a few dollars' worth of proper fixtures in the same place. Let me indicate briefly how little is really needed in order to obtain pictures which rival those from a costly lantern and an electric arc light.

I will assume a school-room into which the sun will shine

directly and having the windows provided with dark colored curtains. A small portable mirror, six or eight inches square, placed on the window sill will permit one to direct its reflected beam to any part of the room all the time the sun shines in that window. Direct the beam across the room so as to fall as a bright spot about midway between floor and ceiling. Next take a double convex lens, about four inches in diameter and one foot focus, and hold it two or three feet from the mirror in the path of the beam. A great disc of light will now appear on the other side of the room. A wooden retort holder will serve to hold the lens in this position, and now if a key or pencil or finger be placed between the lens and the mirror an enlarged and inverted image of the object will appear on the wall opposite, and the outlines may be well defined by moving the object in the beam toward or away from the lens. If the opposite wall be a white plastered wall it will serve well for a screen. If not, a square of white sheeting ten quarters wide or more can be hung there, and removed when not needed, if not on roller. If the lens so used is unmounted, there will be more or less direct light in the middle of the disc, and this may be excluded by fixing the lens in the middle of a board a foot square, through which a hole has been made a little smaller than the lens, to hold it and permit the light to go through. Another retort holder may have fixed in it any lantern transparency or other object to be shown on the screen. The mirror, the mounted lens and the holder for the transparency can be set upon a stand at the window, and its curtain drawn down only so far as to permit the sunshine to fall upon the mirror. Of course, the other curtains may be quite down. But with sunlight one may have bright pictures upon the screen when there is enough light to see easily to read by. The size of the picture on the screen will be equal to the distance of the screen from the lens divided by the focal length of the lens. Thus, if they be thirty feet apart and the lens focus be one foot, the enlargement will be thirty times, so that a transparency three inches square will be seven and a half feet square on the screen.

As described above, the mirror and the lens are but two or three feet apart, but if it be inconvenient to have it thus, the lens can be on the teacher's desk or other convenient place, and a

second adjustable mirror will direct the beam where it is wanted and used the same as before. As the sun slowly moves it is needful to readjust the mirror every minute or two, but having once got the beam and lens in line with the middle of the screen these should not be changed, but only the mirror, so as to shine fully upon the lens in its fixed place.

Diagrams drawn upon smoked glass, or scratched upon thin sheets of mica or gelatin, show well and are easily prepared, while the transparencies made for the lantern are admirably shown.

If the object to be shown be so small that higher magnifying power is needed to be properly seen, such as microscopic things, minerals or insects, there will be needed an additional lens, which may be a common pocket magnifier, a botanical glass, held in the beam of the larger lens near its focus, so all the light from the latter goes through the small lens. The small object, say, the leg or wing of a fly fixed upon a strip of glass, may now be placed between the lenses and near the smaller, and then slowly moved toward the larger. The image will be sharply defined when at the proper distance, and its magnitude will be approximately as in the former case, the distance of the screen divided by the focal length. If the lens focus be one inch and the distance thirty feet the image will be magnified 360 times and a fly's leg one-fourth of an inch long will appear more than seven feet long. A glass tank for holding animalcules may easily be made with two strips of glass four inches long and an inch wide, separated from each other by half a small rubber ring, so as to make a semi-circular pocket and all held together by rubber rings. This will hold, for instance, two or three drops of vinegar, and such eels as chance to be in it may show as so many snakes two or three feet long, wriggling over the screen.

Once more, an object held in this diverging beam from the small lens will show in enlarged outline upon the screen; so apparatus and figures too large to be projected in the ordinary way, and too small to be easily seen at a distance in their details, may be readily shown thus. For instance, an electroscope and its slightly diverging leaves.

There are multitudes of things and phenomena that may thus cheaply be projected. The apparatus needed are the mirror, the

lens and screen. Such a lens as I have described can be had for a dollar and a half, and a carpenter can fit it into a board. A good botanical glass can be had for fifty cents and clamps for holding such things for a quarter of a dollar a piece.

Books are to be had describing experiments of this kind. And if one can afford it, he can get a good porte lumiere for fifteen dollars, which will be more convenient, but not more efficient.

QUANTITATIVE CHEMICAL EXPERIMENTS FOR BEGINNERS.

By G. W. Benton.

On page 15, School Science for March, 1901, Dr. Newell states the fundamental aim in using quantitative experiments to be "to teach the pupil accuracy, confidence, cleanliness, and a profound regard for exact experimental work." On page 13, of the same article, he further says:

> By quantitative experiments we do not mean "research work," nor the simpler determinations which are included in the customary course in quantitative analysis in colleges. Such work cannot be transferred bodily to a high school. It is just here that some teachers and authors have made a fatal mistake, and they are partly responsible for the negative attitude assumed by some secondary teachers toward exact work. Quantitative experiments intended for beginners should possess those elements which characterize all profitable experiments. For example, they should demand only the average degree of manipulative skill. Skill comes by constant, protracted labor. It is an evolutionary product, and is not possessed by beginners, etc.

In the opinion of the writer, the above is sound doctrine. In emphasizing these two statements there is no intention to detract from the merits of the remainder of Dr. Newell's excellent article on "Quantitative Experiments in Chemistry for High Schools." They are quoted simply as an excellent text for the discussion which follows.

The question of quantitative experiments in the first course in chemistry has been under examination in the Shortridge high school for two years and more. The attempt was first made to adapt the experiments proposed by some writers more zealous than wise, who thought the way to reach the child with the

quantitative idea was to reduce to the desired dimensions the typical college experiment, by a process of eliminations, regardless of the fact that the part left was practically a skeleton only, if not merely a few dry bones.

It is needless to say to those familiar with the situation that the first experiments failed. As a result, it became necessary to make experiments for ourselves which should, to a degree at least, meet the prevailing conditions, which the earlier attempts had forced into view. The most apparent of these conditions were:

First, The experiment must involve the simplest manipulation possible.

Second, The details of procedure should be minutely and clearly stated. Nothing must be taken for granted.

Third, Every experiment must be so chosen that the ordinary as well as the very bright pupils can work it out for himself, unassisted by the teacher, as soon as the questions involved are understood.

Fourth, The points of the experiment must be emphasized in concluding remarks.

Fifth, Results must come very close to theory, and sources of error must be easily recognized.

Sixth, The time element must be carefully considered.

These and other conditions of less importance governed the general development of the experiments which grew up one at a time, through various revisions, as the experiences and difficulties of the pupils were encountered. The first series prepared involved twenty-one experiments, which have since been reduced to fourteen, as the limits of the half-year will hardly permit more without seriously interfering with the general descriptive work. These experiments are worked individually and not by the class together. As a consequence, while the quick pupils may complete all of them, the slower pupil, while not working so many, is enabled to do well what he does do. This plan has a two-fold advantage; viz.:

The quicker pupil loses no time in waiting for the slower, and a suggestion from the teacher generally shows the former as well as the latter how two things may be carried on at once, thus saving laboratory time. As it would appear, this is the weak

point of most of the quantitative laboratory instruction in high school courses in physics. This plan means work for the instructor, but it also means "high pressure" for the members of the class.

As a result of the work done to date along the line of the preparation of these experiments, two of them are herewith given with some of the accepted results, not because of any implied belief that a new thing is involved, but as an illustration of a manner of presentation which has been successful in the hands of average high-school pupils:

SIMPLE SOLUTION.

(a) Clean, dry and weigh the beaker. Add about five grams of pure sodium chloride, Na Cl, and weigh the beaker and contents. Calculate the weight of the sodium chloride.

(b) Completely dissolve the contents of the beaker in 100 c.c. of distilled water, transfer the solution to the flask and rinse the beaker twice into the flask, using about 25 c.c. of water each time. Fill the flask to the containing mark and note the volume of the solution. With the flask tightly stoppered with the thumb, stir the solution several times by inverting, and allow to stand for some minutes.

(c) Clean, dry and weigh an evaporating dish. By means of a burette, add to the dish 25 c.c. of the solution in the flask. Evaporate to dryness over a water bath. The dish and contents should be placed in the oven at 105 degrees C. for five minutes, then cooled and weighed. Weigh the dish and contents. Calculate the weight of the contents of the dish.

(d) Make the following observations:

1. Is the solid residue in the dish, salt.
2. What is the ratio in weight of the salt obtained in "c" to the total amount of salt (in "a") with which you started?
3. What is the ratio between the volume of the solution evaporated in "c" and the total contents of the flask in "b"?
4. Compare results in "2" and "3" and make a mathematical statement of the proportion, as

salt : salt :: volume : volume.

5. Predict the weight of salt to be obtained from a second 25 c.c. of the solution. Try it, and verify the results.
6. Is the sodium chloride uniformly distributed through the solution?
7. State some sources of error in your work.

Some results obtained (weights are in grams, and volumes in cubic centimeters):

Weight of salt...	2.61	3.66	5.00	5.00	4.35	6.29	4.99	2.09	4.21	12.32
Volume of flask..	250	250	200	250	250	200	200	250	250	200
Residue No. 1...	0.27	0.39	0.57	0.49	0.42	0.82	0.62	0.21	0.42	1.51
Residue No. 2...	0.29	0.37	0.58	0.48	0.42	0.81	0.61	0.20	0.42	1.45
Average ratio —	1:9.32	1:9.63	1:8.69	1:10.3	1:10 3	1:7.7	1:8.1	1:10.1	1:10	1:8.3
Correct ratio.....	1:10	1:10	1:8	1:10	1:10	1:8	1:8	1:10	1:10	1:8

The errors are easily accounted for, and by a comparison of results it is very readily possible for the most reluctant to arrive at the evident truth.

It is to be understood that only chemically pure substances are used, as the introduction of foreign matter largely diminishes the likelihood of success.

The experiment following presents an interesting fact, namely, that while the process is more involved, the quantities smaller, and the experiment as a whole of a higher grade than the preceding, yet the results are more satisfactory; indeed as good as could be asked under the conditions. While in practice the experiment with salt is given first, as simpler in the matter of manipulation, there are some difficulties to be encountered which materially aid in following experiments, and the usual effect is to make pupils more cautious in taking them up:

CHEMICAL SOLUTION.

(a) Clean, dry and weigh the dish. Add a strip of sheet silver weighing from 0.2 to 0.4 gram. Weigh accurately. Calculate weight of the silver.

(b) Place the dish and silver over a water bath, cover with diluted nitric acid, add two drops of concentrated nitric acid, cover the dish with a watch crystal; and after the silver dissolves remove the cover and evaporate to dryness. Wipe off the outside of the dish, heat to 105 degrees C. in the oven, cool and weigh. Calculate the weight of the crystals.

(c) Dissolve the crystals in about 15 c.c. of water, place over a water bath (individual), and when warm add an excess of sodium hydroxide, NaOH, a drop at a time. Stir the contents of the dish, taking care not to lose any of the dark brown precipitate, and as soon as the liquid settles clear, pour off the liquid, leaving the residue in the dish. Wash several times with water, decanting as before. The last washings should be neutral to litmus. Evaporate to dryness, heat in the oven at 105 degrees C. Cool and weigh. Calculate the weight of the brown residue in the dish.

(d) Place the dish and residue on a ring of the ring-stand and heat evenly with the blue Bunsen flame until the brown color of the residue is replaced by a white luster. Cool and weigh. Calculate the weight of the residue.

(e) Make the following observations:

1. Compare the weight of the residue in "d" with the weight of the silver used. Compare the products (?).

2. With a knife carefully scrape the silver from the dish and return to the instructor. To the remaining particles in the dish add a few drops of diluted nitric acid, warm and convey the solution to a test tube. Add 10 c.c. of water and two drops of diluted hydrochloric acid. Then add an excess of ammonium hydroxide (?).

3. Now take 5 c.c. of a solution of silver nitrate in a tube, add two drops of diluted hydrochloric acid, and then ammonium hydroxide in excess. Compare the results in "2" and "3." If "3" is a test for silver, what can you say about the nature of the final product in "d"?

4. Are the changes in "b," "c" and "d" manifestly physical or chemical?
5. Has the treatment of the silver destroyed it?
6. Equations—These will be studied later. Put them down:
7. The underscored products in "b," "c" and "d" in "6" are respectively white, brown and white.

Some results obtained:

Wt. of silver	0.20	0.17	0.34	0.13	0.23	0.43	0.29	0.21	0.28	0.20	0.35	0.24	0.18
Wt. of crystals ..	0.33	0.25	0.54	0.22	0.36	0.67	0.49	0.33	0.43	0.32	0.57	0.39	0.29
Wt. of brown res. . .	0.21	0.18	0.38	0.15	0.26	0.46	0.29	0.23	0.30	0.22	0.40	0.26	0.21
Wt. of silver res.	0.195	0.16	0.34	0.13	0.23	0.41	0.27	0.19	0.28	0.19	0.35	0.23	0.175
Error	0.005	0.01	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.01	0.00	0.01	0.005

In nearly every case the pupil readily observes that the loss may have occurred in the process of decanting, which loss with proper care might have been avoided and in every case the correct result was the work of the more thoughtful.

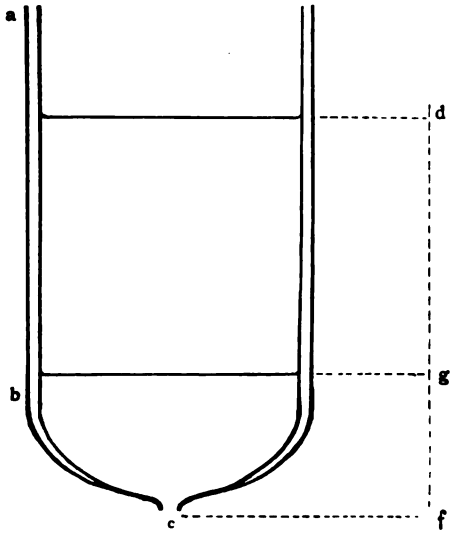
It is worth while to note that the weighings were made on balances sensitive enough to weigh to 0.01 g., estimating to 0.005 g. Very few took the trouble to estimate the latter, which, of course, could readily account for a portion of the error. These balances (we have ten of them), which were made to order, will appeal to teachers, and for their information the following illustration is given:

They are all glass and aluminum, costing less than $14 each, and after three years of use, standing in the main laboratory, are still in first-class condition. The only repairs so far needed were made this winter on the counterpoised doors of four of the balances, which had suffered unusual treatment at the hands of unskilled manipulators.

A DEMONSTRATION OF CAPILLARITY*

BY V. DVORAK.

The following demonstration is easily carried out and may be plainly seen even at quite a distance; it can also be nicely projected.



A glass tube *ab* (Fig. 1) 13 mm. in diameter is drawn down very abruptly so that its end *c* is as short and thin as possible; the diameter of the orifice is about 5 mm. If water is poured very

*Translated for "School Science" from Physikalische Zeitschrift, II, 223.

slowly into the tube, I found with my tube that the height of the water column was about 22 mm.; when more water was added a portion flowed out.

When alcohol is poured into the tube, the height *fg* of the liquid is considerably lower, though the specific gravity of alcohol is less than that of water. The column of liquid is supported by the surface film at *c*, and the surface tension of water is 7.5 mg. per mm., of alcohol only 2.5 (of ether 1.88).

Still more striking is the following experiment. The tube is filled as full as posssible with water. Then a few drops of ether are poured into a small beaker which is subsequently held up around the tube. The water begins to drop out at once but ceases to do so as soon as the beaker is removed. The vapor of the ether dissolves in the water at *c* and lessens its surface tension considerably.

AN "INDEXOMETER."

By J. Stewart Gibson.

Instructor in Physics, Wadleigh High School, N. Y. City.

The essentials of this simple device for determining the index of refraction of liquids are: (1) A tumbler (or any small cup) filled level-full with water or other liquid whose index of refraction is to be determined; the tumbler may be placed in a shallow dish to prevent spilling. (2) The device proper is figured one-half size in the accompanying drawing (Fig. 1). It consists of a horizontal bar of wood (paraffined pine) 5 inches long, 1 inch wide and ½ inch thick, at one end of which and perpendicular to it is fastened another bar, ½ inch by ½ inch and 4 inches long. On this upright bar or post is arranged a movable sight-edge made of a strip of sheet brass bent around the post so that its edge projects backward (as figured) about ½ inch perpendicular to the post and in the plane of its end face. The horizontal bar is notched on its under surface at the middle where a pin is driven through and cut off so that its point is just in line with the lower back edge of the bar. About an inch from the opposite end of the

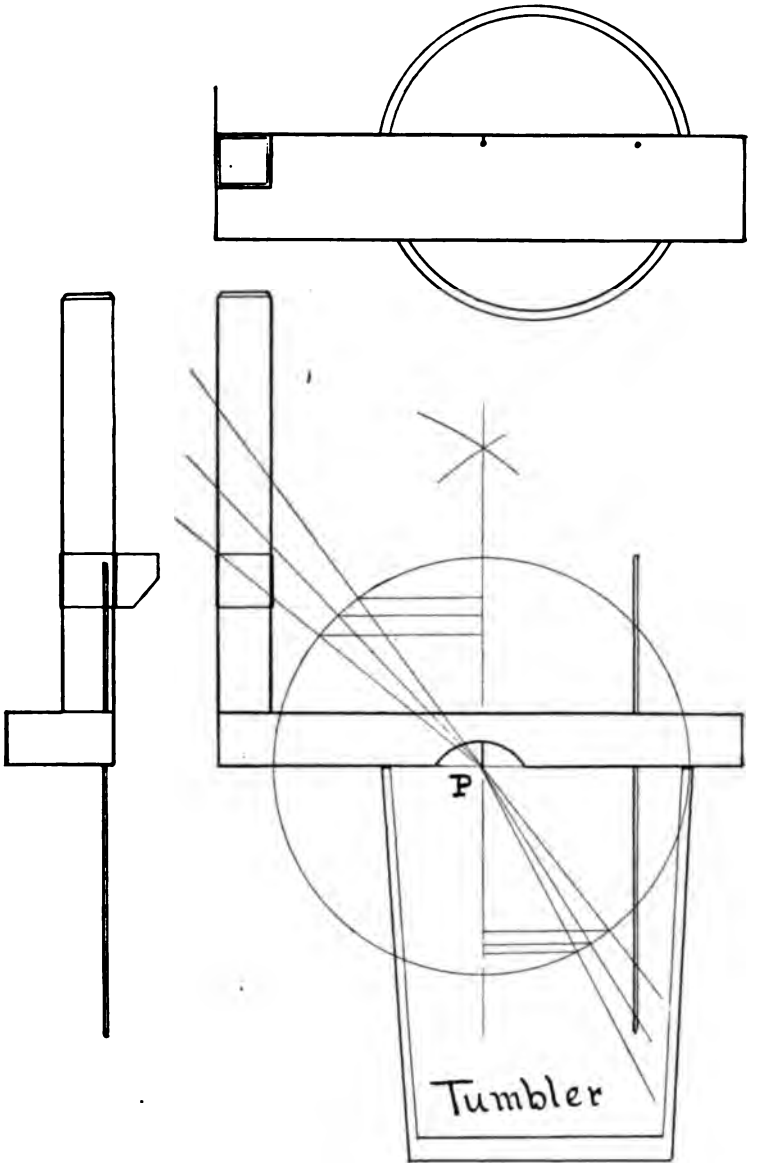


Fig. 1.

bar and close to the back edge a small hole is made through which a half knitting needle is thrust at right angles to the bar.

The bar is placed on the tumbler as shown in the figure, care being taken to have the pin-point come as close as possible to but not touch the liquid surface. Then the sight-edge is adjusted so that it appears to be in line with the pin-point and the needle-point in the water.

The measurement may be transferred directly to the note-book by marking off on two lines, drawn at right angles, the position of the sight-edge on one and that of the pin-point on the other, also marking the position of the needle-point. Then with any convenient radius and the pin-point as a center describe a circle; construct a perpendicular through the pin-point; draw the path of the incident ray from the needle-point to the pin-point, and that of the refracted ray from the pin-point to the sight-edge; finally construct, measure and compute the ratio of the sines.

By varying the length of the needle two or more pairs of angles may be measured in the same figure and the constant ratio of the sines thus clearly shown.

The results are surprisingly accurate, coming within one or two per cent with the average pupil; while the simplicity of the apparatus and the directness of the operation both recommend it for individual laboratory work.

AN EXPERIMENT TO DETERMINE THE APPARENT COEFFICIENT OF EXPANSION OF A LIQUID.

By F. A. Osborn.

Professor of Physics, Olivet College, Mich.

The following method of determining the coefficient of expansion of a liquid has been in use for three years in my laboratory and has given such excellent results that other teachers may be glad to have their attention called to it.

An air-thermometer bulb, with a rather large capillary stem, is the chief piece of apparatus. Weigh the empty bulb, and then fill it with boiled distilled water so that the water in the stem is

3 or 4 cms. from the bulb, when it is at the temperature of the room.

The bulb can be best filled by supporting it in a vertical position in a water bath with the open end of the stem connected to a small funnel by means of a rubber stopper. Pour the distilled water into the funnel and heat. Air will bubble out through the water; after a few minutes stop heating; the water will run into the bulb as the air contracts. Repeat these operations until the bulb is filled. Take the bulb out of bath and leave it to cool, removing the funnel when the bulb has reached the temperature of the room. The desired position of the water in the stem can be obtained by heating the bulb with the hand, thus causing some of the liquid in the stem to flow out.

The bulb, being filled to the desired point (which should be marked by a scratch on the stem), is now carefully weighed. The mass of the water in the bulb may be found from the two weighings. From a table get the density of water at the given temperature, and then compute the capacity of the bulb and stem up to the fixed point.

The capacity at 0°C. may be found by the equation:

$$v^{\circ}=v'\ (1-0.000026t).$$

The bulb is now to be emptied, dried, and the stem filled with pure mercury for a distance of 10 or 20 cms. Determine carefully the length of this mercury filament and the weight of the bulb and mercury. From these data obtain the area of the cross-section of the stem.

The work so far is preliminary, and is done by students in the fall term, as two exercises in the use of the balance.

The bulb is now to be filled with the liquid whose coefficient of expansion is to be found. Turpentine, sweet oil, glycerine are good liquids. When filled, immerse the bulb in finely crushed clean ice. When the liquid has reached the temperature of the ice, as shown by the liquid in the stem remaining stationary, mark position by sticking to the tube a piece of paper. Remove the bulb, place it in a beaker of cold water and raise the temperature about 20 degrees, if this temperature does not cause the liquid in the stem to overflow. Stir the water constantly and mark the

position of the liquid when it begins to fall after having reached its maximum point. Read the thermometer at this time. With a millimeter scale determine carefully the distance between the two marks.

From the data thus obtained, knowing the volume of the bulb and the cross section of the stem, the coefficient of apparent expansion may be computed. For if $v°$ be the volume of the liquid at o°C., and v' its apparent volume at the temperature t, then a, the coefficient of apparent expansion, is given by the equation:

$$v' = v° (1 + a t),$$

or

$$a = \frac{v' - v°}{v° t}$$

DATA FROM A STUDENT'S NOTEBOOK.

Weight of bulb, full.....66.790 g.
Weight of bulb, empty.....30.960 g.
Weight of water.....35.830 g.
Weight of 1 c.c. of water at 12.2 degrees C..... 0.999 g.

Capacity of bulb and stem to fixed point (35.830 | 0.999)=35.865 c.c.
Capacity of bulb and stem at o degrees C., 35.865 (1—0.000026x12.2)= 35.844 c.c.

Length of mercury filament.....14.8 cms.
Weight of mercury and bulb.....35.576 g.
Weight of mercury..... 4.616 g.
Area of cross section of stem, 0.0229 sq. cm. Density of mercury, 13.599.

Elevation of surface of liquid in stem.	Temperature.	$v-v°$.	a.	Liquid.
11.30 cm.	15.0 degrees	0.2587	0.000481	Glycerine
12.30 cm.	16.4 degrees	0.2816	0.000479	Glycerine
10.40 cm.	13.8 degrees	0.2381	0.000481	Glycerine

A Dumas Tablet.—A bronze tablet in honor of J. B. A. Dumas has been placed in the house in Rue St. Dominique, Paris, where the brilliant chemist lived for many years.

Metrology.*

THE METRIC SYSTEM IN ENGLAND.*

Not long ago the eminent metrologist, Dr. F. C. Mendenhall, stated that the metric system had made more progress in five years in England than in thirty years in this country. Any one familiar with the literature of the subject will say this seems well within bounds. In fact, in our own country no single law has been enacted on the subject since 1866, whereas in England the last important act was in 1896.

Let us scan briefly the legislative history of this progress from the first important act of Parliament. The legal aspect of weights and measures and the controversy resulting would form an extremely fascinating volume of English history, and one having no small bearing on the revolutions in that country, starting from that Magna Charta, "the first legislative act in the English statutes at large" (Henry III., 1225), which had much to do with weights and measures. All such points must be left for future consideration, it being our present purpose to speak of that part of the subject which bears on the metric system only.

When in 1790 the constitutional assembly of France adopted Talleyrand's plan of decimalization, it was proposed that a joint commission from the Royal Society of England and the French Academy should work out the details of the plan. The failure of Parliament to reply to the request of the Royal Society and to accept has cost Great Britain more than a hundred years of metric misfortune and also placed her in the rear rank of nations as regards coinage. It was a gigantic mistake. It seems doubtful whether the coöperation of English scientists with the French would have materially changed the decimal division, though the nomenclature might possibly have been varied. Since that time Parliament has at various times appointed committees on weights and measures that continued to recommend the old systems, until 1862, at which time a select committee reported in favor of the

* Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

metric system as best fulfilling the conditions of a simple and uniform system of weights and measures, but suggested that it be not made compulsory.

Following this recommendation, Parliament passed the act of 1864, legalizing the system, thus antedating by two years our own permissive law. The continued appointment of committees having the same object in view, shows as clearly as anything can that the systems in use at present are unsatisfactory, illustrating the thought that nothing is settled till it is settled right. In nearly every country this has been the history of metric legislation—first reaffirming the old, then patching it up, and finally abolishing it entirely and substituting a system in harmony with the arithmetic of civilization.

Four years later a bill for compulsory use in Great Britain barely escaped enactment, which again put back the reform. Tides fall as well as rise, and the act of 1864 was practically nullified in 1878 by a law which forbade the use of any weights or measures which were not Board of Trade standards. As this body knew not the meter and kilo, it became criminal for a citizen to employ them. It was no hardship, however, for permissive use among a people educated in an old system, no matter how crude, has never gained much more headway than permissive honesty among thieves. It was not until 1896 that this absurd law was repealed, and the legality of the metric system re-established. This is the last measure regarding popular usage which has passed, and like its predecessor contains no compulsion to either citizen or government.

What has been done outside of legislation? In 1890 there was formed the Decimal Association, with headquarters in London, "to promote the adoption of a decimal system of weights, measures and coinage in the United Kingdom." It was decided to try to decimalize weights and measures first and coinage afterward. Made up of a large number of educated, influential and business men, this organization is accomplishing much in molding public opinion, and enlightening the legislator and the tradesman. Its committees include members of the houses of Peers and Commons, of chambers of commerce, of school boards, of trades councils, as well as accountants, assayers, bankers, engineers,

electricians, manufacturers, merchants and foreign traders, scientists, shipowners, warehousemen, etc. Sir Samuel Montague, Bart., M. P., is president; J. Emerson Dowson, M. Inst., C. E., chairman of executive committee, and Edward Johnson, secretary. The names of members fill several pages. This live association, with its active secretary, is reaching out in every direction. It has influenced the educational department to require thorough teaching of the metric system in all the day schools, beginning, as is done on the continent, with the lowest grades. Such universal teaching in the schools is sure sooner or later to bring about metric reform. Compulsory education stimulates the production of textbooks, and as a result more works on the metric system were issued in 1900 than in any previous year. The association has arranged to give popular lectures on its favorite subject in the leading cities and towns, thus familiarizing the mechanic, the laborer and the banker with the new implements of culture. By a personal canvass, made largely by the secretary, 150 members of Parliament have pledged support to a metric law making the use of the system compulsory after two years, and twenty more members are known to favor it. Committees of Parliament have again and again urged the passage of a metric law. One of the latest ideas of the Decimal Association is an attempt to arrange a conference in Paris of official delegates from England, the United States and Russia for a concerted movement in those three countries. Business men are beginning to see that it is for their interest to hasten the reform movement. In Liverpool alone no less than ten of the largest commercial and manufacturing associations have come out ardent advocates of decimalization, nor is this exceptional, for in London and other large cities the same is true. Last June the Congress of Chambers of Commerce of the British Empire, held in London, passed resolutions strongly favoring the adoption and compulsory use of the international system. The great Salford Iron Works of Manchester issued instructions March 1, 1901, to draftsmen, manager and foremen, as follows:

> From this date in all plans for the works, or to be sent to customers, dimensions must be given in English measure and also in the equivalent metric measure. Measurements on new lithographed plans are to be similarly given in both measures. All plans to go out to countries in which the metric system is in general use must be dimensioned in metric measure only, etc.

As a sample of enlightened opinion combined with experience the following from the evidence of Sir Benjamin Baker, ex-president of the Institution of Civil Engineers, before the select committee of the House of Commons in 1895, is suggestive:

> I know hundreds of English engineers who have drifted necessarily into the metric system and the decimal system, and I have never heard one who would come back to the English weights and measures if they had the option.

With all the committees, chambers of commerce, manufacturing and mercantile associations, boards of trade and educational societies behind the movement, England seems much nearer to metric reform than is our own country. The members of these associations read from the reports of their consuls all over the world that Great Britain is at a serious disadvantage with her antiquated measurement units in regard to foreign commerce. At this time, when she is viewing with alarm the danger of losing to the United States the prestige of her manufacturing and exporting industries, by reason of vast concentration of wealth, and is feeling the necessity of laying hold of every favorable point of competition, it will be surprising if she does not within the next few years pass a compulsory metric law.

NOTES.

The American Metrological Society held its annual meeting April 19, 1901, in Washington, Dr. F. C. Mendenhall presiding. Prof. W. S. Stratton, the recently appointed director of the new Standardizing Bureau, gave an outline of its nature and functions, which will be described at length in a subsequent number of SCHOOL SCIENCE. He stated that the influence of the Bureau would be exerted in favor of the metric system. Dr. W. H. Seaman, of the Patent Office, urged that the next movement for the use of the metric system be upon the Post Office Department. Dr. Mendenhall stated that a letter weighing more than an ounce but less than 30 grams requires but one 2-cent stamp, he having made and sent such a test letter. Mr. A. L. Baldwin, of the United States Coast and Geodetic Survey, read a paper, the subject of which was not reported.

Various plans for promoting the adoption of the metric system were discussed. The sending to our new colonial possessions of school arithmetics containing our antiquated tables and problems of customary weights and measures, was deplored and a committee was appointed to

urge upon the departments the advisability of retaining the weights and measures already in use there—viz., the international system. Another committee was created having for its object the persuasion of the Post Office Department to adopt the metric system of weights.

An encouraging item was the statement that New England manufacturers are reported to have great interest in the system as necessary for the promotion of exports. A member who was present writes: "There were several events that seemed to show a stronger drift toward the metric system than I have ever seen before."—Prof. J. H. Gore, of Columbian University, is the Permanent Secretary.

Metric Reform in Denmark.—Mr. Jules Blom, formerly of the United States Consular service, writes from Copenhagen on Jan. 12, 1901, as follows: "In reply to your favor of Dec. 31 the chairman of the committee informs me that they are working hard on the introduction of the metric weight and measure system, but that he does not expect the law will be passed during the present session of the Danish legislative body. I shall watch the case and inform you as soon as there is an occasion."

Notes.

MISCELLANEOUS.

The Science Teacher's Vacation should be a season of growth, not of stagnation. While your work during the year has been hard and strength-sapping, it is not sheer idleness or absolute rest you need, but rather a change of occupation. Unless in poor health, it is not doing nothing that will prepare you best for the next year's work, but rather doing something that is a change from the old routine. If possible go away from home; get into new scenes and different surroundings for a time. Attend an educational meeting. The National Educational Association meets in Detroit, a very central and accessible location and convenient to the Pan-American Exposition at Buffalo. While the N. E. A. has not in the past been especially attractive to most teachers of science, there is a movement on foot to organize an auxiliary association for science teachers. Although this movement is still in the gristle, it has great expectations and asks the co-operation of all aggressive and progressive science teachers. Then there are the summer schools and the biological laboratories, as at Wood's Holl, Cold Spring Harbor, etc. You have been giving out all the year, why not take in a little during the

vacation? The change from teacher to learner is most refreshing. You can get more *real* rest by working in a summer school than you can by remaining dully at home. And the new things you will learn, the friendships you will make, the inspiration you will find, all will fit you for next year's work as nothing else can do. You will enter upon it with renewed vigor and confidence, you will find it more interesting and agreeable, your students will be benefited and your Board will be appreciative.

Free for the Asking.—A list of books in chemistry has been prepared by the New England Association of Chemistry Teachers. It contains about one-hundred annotated titles and was compiled by a committee of the association for the use of teachers and pupils in secondary schools. A copy of this list may be obtained without cost from the L. E. Knott Apparatus Co., Boston, Mass.—*The Ephemeris of Materia Medica, Pharmacy, etc.*, for January, 1901 (Vol. VI., No. 3), has just been issued by Dr. E. H. Squibb, Brooklyn, N. Y. Copies will be sent without charge to any interested applicant as long as the supply lasts. The information in this series of unique pamphlets is reliable, scientific and interesting. It is designed for those who are interested in the application of chemistry to medicine, especially to the newer remedies.—Baker & Co., Newark, N. J., have just issued for free distribution two placards, 16 to 30 cms., suitable for posting in the laboratory. One is a comparison of troy, avoirdupois and metric weights, and the other contains detailed directions for the care, use and cleaning of platinum ware.—The Eastern Association of Physics Teachers has issued an annotated list of books in physics adapted especially for teachers and pupils in secondary schools. A copy will be sent to any teacher on request by Mr. F. R. Hathaway, Secretary, Salem (Mass.) High School.

High School Scientific Club.—A small scientific society has been organized in the High School at Clinton, Iowa, and is proving a decided success. It is called the "Newtonian Club," in honor of Sir Isaac Newton, and its membership, consisting mostly of junior and senior students, is limited to twenty. Meetings are held in the high school building every Saturday evening, the program consisting of a leading paper by some one of the members, followed by discussion and voluntary reports on current scientific subjects. Some of the topics that have been dealt with so far are: "Unconscious Activities," "Is Mars Inhabited?" "Practical Uses of Compressed Air" and "Ants, Their Habits, Senses and Intelligence." Everything is quite informal, and some fascinating secret features contribute much to the interest. The society is planning some excursions to various points of interest in and about Clinton. It is the opinion of the writer that such societies should be established elsewhere in high schools, as they tend to promote interest and to bind student and teacher in one common cause.

The "Newtonian Club" is a subscriber to SCHOOL SCIENCE.

Department of Physics and Chemistry. LEROY D. WELD.

ELECTRICITY.

The Number of Alternations of a current can be shown very nicely by the pitch of the note produced by an iron plate set in vibration by an electromagnet. An iron disk about 0.5 mm. thick and 20 cms. in diameter is fastened on a bed of felt in a wooden ring and clamped a few millimeters over an electromagnet. When a strong alternating current, as one from an electric light plant, is sent through the electromagnet, the disk starts to vibrate, and the pitch of the note produced is an indication of the frequency of the alternations. The note is surprisingly strong.

Zeitschr. f. phys. und chem. Unterricht, XIII. 313. **HANS LOHMANN.**

The Mapping of Electric Lines of Flow. A piece of filter paper is laid upon a glass plate and wet with a solution of zinc sulphate. Over it are sprinkled fine zinc filings. The terminals of a strong direct current (a house current of 110 volts) are pressed down upon the paper at some distance apart. When the circuit is closed the electrolytic precipitate from the filings soon brings out clearly the distribution of the lines of flow. Different combinations with respect to the number, position and form of the electrodes give rise to a great variety of figures. Beautiful figures are obtained when conducting substances, as metallic plates, are placed in the way of the current, or portions of the paper are cut away so as to interpose non-conducting places. Other electrolytes and metals may also be used, but zinc sulphate and zinc seem to give the best results.

Zeitschr. f. phys. und chem. Unterricht, XIII. 336. **A. ZINGER.**

Book Reviews.

Studies of Animal Life: A Series of Laboratory Exercises for the Use of High Schools. By HERBERT E. WALTER, WORRALLO WHITNEY and F. COLBY LUCAS, Instructors in Biology in the Chicago High Schools. 13x18 cms., vi. and 106 pages. D. C. Heath & Co., Boston. 1900. $0.50.

In the words of the authors: "The subject-matter of this book is animal life and not animal forms, the authors' point of view being to study living animals and to interpret their activities, so far as possible, instead of compiling a series of zoölogical obituaries."

It is refreshing not to be told again why it is better to go from the simple to the complex, etc., or that the study of animals may begin anywhere.

The microscope and the cell are the preliminary study. In a clever way the student is made to realize that the compound microscope gives an inverted image. Then Protozoa, Sponges, Coelenterata, Worms, Echinoderms Arthropoda Mollusca and Vertebrates are studied in the usual order given in such books.

Most of the studies consist of habitat (explained by instructor), hab-

its—observed usually in living animals in the laboratory—general external morphology as far as possible from live or fresh animals under observation, and internal anatomy in enough cases to give an idea of the location and appearance of the principal organs. Fortunately life activities form a large part of each study, as promised. The comparison that frequently follows —a type with its related form—is valuable, but it must be regretted that such comparisons are not used to convey the idea of relationships. We miss, likewise, all through, the doctrine of descent, and this omission is surely not due to the difficulty of the subject, for more difficult questions are asked and their answers expected.

The extent to which the question method is used is commendable. In too many books, mere directions lead the student to fitting his animal to the directions, and he loses, rather than gains, independence. But we believe it is a defect in the method when questions are asked that are beyond the pupil's ability to answer.

On the whole, the little book gives evidence of being based on experience, and readily commends itself to those intending to use a manual.

L. M.

Text-Book of Inorganic Chemistry. By VICTOR VON RICHTER. Edited by Prof. H. KLINGER. Authorized translation by EDGAR T. SMITH, Professor of Chemistry in the University of Pennsylvania (assisted by WALTER T. TAGGART). Fifth American from the tenth German edition. 14x21 cms., 430 pages. P. Blakiston's Son & Co., Philadelphia. 1900. $1.75.

The latest American edition of this standard text-book has substantially the same form and arrangement as its predecessors. It contains a large amount of authentic material in a limited space, and the typography allows the more essential parts to be readily selected from those of lesser importance. The main difference from preceding editions consists in the consideration given by the editor to the more recent well established discoveries and theories. The revision covers among other subjects the general properties and the measurement of gases, the recently discovered constituents of the atmosphere, the alloys, the electrolysis of salts and the theory of electrolytic dissociation in its different phases. The treatment of some of these topics is rather condensed, but it is sharp and to the point, differing markedly in this respect from the generous but often hazy consideration recorded in the larger books. In most cases the editor has retained the essential facts, leaving the reader to find for himself the illustrations and applications in the original articles, to which references are abundant. It is to be regretted, however, that the translator did not take the liberty—by all means warranted—to incorporate more references to English sources, especially since many important articles have been translated. The college teacher forgets that even though many teachers in secondary schools read German, they have no access to files of German periodicals. The same criticism may be made of the references to books. Scarcely an English book is mentioned, though the German titles are super-

abundant. This book is too difficult for pupils in secondary schools. It is, however, a good book for a school library. Teachers who have no recent book in inorganic chemistry will find this book a valuable adjunct to their library. Few adverse criticisms need be made. The illustrations are uniformly bad. The discovery of oxygen by Priestley is stated as 1771 instead of 1774. Willson, whose work on calcium carbide is well known, is spelled with one and with two l's. Metargon is recorded among the recently discovered gases in the atmosphere, but it is now known to be "non-existent." These and similar errors, however, do not detract from the general usefulness of the book. LYMAN C. NEWELL.

Lessons in Botany. By GEORGE FRANCIS ATKINSON, Ph.B., Professor of Botany in Cornell University. 13x19 cm., xv. and 365 pages. Henry Holt & Co., New York. 1900. $1.12.

Professor Atkinson's book is divided into the usual parts under Physiology and Morphology and the now well recognized part under Ecology. There is one refreshing thing about the author's treatment of the subject of Physiology—he introduces with the experiments sufficient matter for reading and reference to keep up the interest while the student is necessarily waiting for the full results of the experiments, this matter being largely devoted to the structures and mechanisms by which the plants carry on their functions. Again, the author has broken over the common custom of confining physiological work to the phanerogams and has introduced a few cryptograms in their proper place for showing some of the simpler processes. It would have been better, so far as they are illustrative, to have introduced higher and higher forms as the higher and more complex functions were described. This would have given an equal balance to the lower and more developed forms, a balance rarely appreciated by the secondary school student.

Under Morphology are included two groups of facts. Perhaps rather with, than under, Morphology is brought out quite fully the significant life-history of representative forms. After the chapters dealing with these strictly, follow several chapters based on the characters of different plant families, bringing out in successive steps the gradual changes and developments, chiefly reproductive, of course, shown in a series from the simplest to the highest. This feature should give most excellent results in awakening the pupil's interest in the natural surroundings in which he is. And the author may be assured that this idea is not a prominent one in the long list of comparatively recent books on botanical study.

Under Ecology the author has taken up the more usual modern line of treatment, which needs no comment in this place.

It is a little unfortunate that the illustrations are to such an extent printed from rather dark plates. This makes too great a contrast between them and the text. The typography is excellent for the declared purpose of the book. The presswork is weak at the headings of chapters, where the upper margins are in many cases rubbed, otherwise very satisfactory.

E. L. M.

Books Received.

Experiments arranged for Students in General Chemistry. By Edgar F. Smith and Harry F. Keller. Fourth edition, enlarged, with 41 illustrations. P. Blakiston's Son & Co., Philadelphia, 1900. iii and 88 pages. 60 cents.

3500 Questions on Medical Subjects arranged for Self-Examination. Third edition, enlarged. P. Blakiston's Son & Co., Philadelphia, 1901. viii and 230 pages. 10 cents.

Wild Birds in City Parks. Being hints on identifying 100 birds, prepared primarily for the spring migration in Lincoln Park, Chicago. By Herbert Eugene Walter and Alice Hall Walter. Chicago, 1901.

Bulletin of the Geographic Society of Chicago, No. 2. The Plant Societies of Chicago and Vicinity. By Henry C. Cowles, Chicago. Published by the Geographic Society of Chicago, 1901.

Systematic Science Teaching. A Manual of Inductive Elementary Work for all Instructors. By Edward Gardnier Howe. D. Appleton & Co., 1900. xxix and 336 pages. $1.50.

Advanced Elementary Science, Being Part II of Systematic Science Teaching. A Manual of Inductive Elementary Work. By Edward Gardnier Howe. D. Appleton & Co., 1900. xiii and 373 pages. $1.50.

First Studies of Plant Life. By George Francis Atkinson. Ginn & Co., Boston, 1901. xii and 266 pages. 60 cents.

CLEARING HOUSE.

Teachers desiring to offer for exchange books, apparatus, etc., may insert a notice to that effect at the nominal rate of one cent per word, *in advance*.

Reports of Meetings.

NATURAL SCIENCE ASSOCIATION OF ONTARIO.

The association held its annual meeting in Toronto on April 9 and 10, in connection with the meeting of the Ontario Educational Association. At the first session an able address on "Nature Study for Observation and Information in Public Schools" was given by the President, W. S. Ellis, B.A., B.Sc., Kingston. After a very full discussion a committee was appointed to draft an outline of Nature Studies and to urge upon the Departments of Education and of Agriculture the necessity for making nature study occupy a more important place in the elementary schools.

Then followed the report of the committee appointed last year to draft a "Programme of Science Studies" for high schools. It was unanimously resolved to have the committee urge upon the Education Department the desirability of making radical changes in the present science programme, especially in the science required for junior students.

At the next session the association had the pleasure of hearing W. K. T. Smellie, B. A., principal of the high school, Deseronto, give a paper on "Charcoal Iron." Mr. Smellie pointed out the special field for charcoal

smelting in Ontario, where coal is difficult to secure. The Deseronto smelting works were described and used to illustrate the paper.

J. A. Fife, B. A., of Peterboro, gave an account of some original work done in connection with the Canadian woodpeckers, specimens of which he used for illustrating his field notes.

The secretary reported on "Recent Scientific Books." He called attention to the excellent little books for practical work in botany and zoölogy published by Messrs. Heath & Co. These were "Studies in Animal Life" and "Studies in Plant Life." Several volumes of Appleton's "Twentieth Century Series" were also exhibited and highly recommended to all teachers of science. Particular attention was called to "Plant Studies," by Dr. Coulter, and "Animal Life," by Drs. Jordan and Kellogg.

SCHOOL SCIENCE was brought to the attention of the members and sample copies were presented. The speaker showed the importance of having such a periodical to stimulate one's thought and keep one's teaching "up to date."

A joint meeting was held with the Physical Association, at which Dr. J. C. McLennan, of University College, gave a demonstration and a report upon "Some Recent Advances in Electrical Science," dealing in a scholarly way with leakages, etc.

In connection with the Educational Association the members had the pleasure, on Wednesday evening, of hearing Prof. J. W. Robertson, Dominion Dairy Commissioner, give an admirable address on "Manual Training." Professor Robertson, through the munificent gifts of Sir W. C. MacDonald, has been able to establish in every Province of the Dominion one or more schools to give an experimental proof that manual training should have a much larger place in all our work.

Reported by E. L. HILL.

INDIANA STATE SCIENCE TEACHERS' ASSOCIATION.

The sixth annual meeting of the association was held at the State Normal School, Terre Haute, on Friday and Saturday, April 26 and 27, 1901. The session of Friday morning was devoted to papers of a general character. The meeting opened with an address of welcome by President W. W. Parsons. Dr. D. W. Dennis, of Earlham College, followed with a very instructive paper on "The Culture Value of Science Study," in which he admirably showed that the modern presentation of science is calculated to furnish fully as high a grade of culture as that to be derived from the so-called humanities.

The acting president, G. W. Benton, of Shortridge High School, Indianapolis, followed with a brief address on "Professional Elasticity," in which he urged a broad culture, with unquestioned professionalism, but extensive contact with affairs out of the class-room and laboratory, and particularly business and travel experience. The session closed with the appointment of committees.

The afternoon session of Friday was opened by Dr. C. B. Davenport, of the University of Chicago, who gave "A Review of the Different Methods Employed in Teaching Biology." His paper dealt with the historic side of science teaching largely, showing the main reasons why in succession the text-book method, the lecture method, the class-laboratory method, the laboratory guide method, etc., had gradually passed away and why the study of nature, as proposed by Agassiz, but modified by the conditions of time and place, has become universally recognized by advance thinkers as the true way. He urged the teaching of truth as observed, not as the books describe it.

The discussion was opened by Prof. Donaldson Bodine, of Wabash College, and Prof. Mel. T. Cook, of De Pauw, who spoke in support of the general points of the paper.

The next paper was on the subject "Physics in High Schools and Grades," by President C. L. Mees, Rose Polytechnic Institute. The speaker took the ground that physics is the only science which has no place in the grades, it requiring too great maturity of mind for pupils at that age. He also expressed the conviction that much of the physics now taught in high schools was too technical, and beyond the ability of the mass of pupils. He thinks that to do very effective work in physics in the average school it will be necessary to materially simplify the course. Dr. Mees also said that not less than a year should be devoted to the subject, and more time could be used with profit if available, otherwise it should be omitted.

Dr. Mees' paper was discussed by Mr. Crowe, of Fort Wayne, and Mr. Bruce, of Princeton, who enlarged upon the necessity of simplifying the courses in high school physics and particularly the importance of the analysis of problems, as against the use of formulae.

Following the close of the afternoon session the members took a trolley ride over the new Terre Haute-Brazil electric line.

At 6 p. m. the members of the association banqueted at the Terre Haute house.

The evening session was devoted to an illustrated lecture on "Wireless Telegraphy," by Mr. W. J. Clark, of New York. The lecture was given in two parts; the first, illustrated by stereopticon, presented the historical phase of the subject, with a very clear presentation of the development of the induction coil and its applications. The second part was a practical demonstration of the work which can be done. The apparatus was well handled, and motors were run, lights turned on and off, messages sent, etc. The experiments worked to the entire satisfaction of the audience.

The closing session was held on Saturday morning. Dr. J. T. Scovell, of the Terre Haute High School, spoke informally on the subject of "Commercial Geography," sketching the history of transportation in this country particularly and calling attention to the present revival of

interest in ship canals and the prospects for future commercial progress as a result.

The first formal paper of the morning session was "The Study of Bacteria in High Schools," by Prof. A. J. Bigney, of Morris Hill. He favored the study of simple sanitary methods rather than the formal study of the science.

The paper was discussed by Prof. Rettger, Dr. Scovell, Prof. McBeth, Mr. Benton and others. Discussion favored the study of sanitary science from the non-technical side, but a feeling was expressed that it might profitably be placed in the lower grades, as a phase of nature study.

The last paper of the session was on "Nature Study in the Schools," presented by Mr. F. M. Mutchler, of Terre Haute. The paper was discussed by Prof. Caldwell, of the Eastern Illinois Normal School, Dr. Rettger, Dr. Scovell and others. Both paper and discussion advocated the teaching of simple truth to the exclusion of myth and fairy tale.

Officers were chosen for the coming year as follows:

President, J. T. Scovell, Terre Haute; vice president, J. H. Voris, Huntington; secretary, D. C. Weir, Indianapolis; treasurer, J. F. Thompson, Richmond; executive committee, M. E. Crowell, Franklin; L. E. Wheeler, Monticello; Leonard Young, Evansville; John Owen, Huntingsburg; Donaldson Bodine, Crawfordsville.

The papers and discussions will appear in the published proceedings to be issued some time during the summer, under the editorial direction of Prof. L. J. Rettger, State Normal School, Terre Haute, Ind.

Reported by G. W. BENTON.

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS.

The eleventh regular meeting of the association was held Saturday, April 20, at the Institute of Technology, Boston, Mass. President Rufus P. Williams was in the chair and about twenty-five members were present. After the usual routine business the Committee on Reference Books reported verbally that their work had been completed and the list of books was ready for distribution.

In the course of the meeting a package of the list of books was received from the publishers, L. E. Knott Apparatus Company, for distribution among those present, and it was accompanied by a note stating that three copies were ready for mailing to each member.

It was voted to appoint a committee of three to consider the matter of chemistry as a college entrance subject and to report at the next meeting. Dr. Lyman C. Newell was appointed by the Association and Mr. Lyman G. Smith by the Executive Committee to serve with another on this committee (to be selected by the two members already appointed). Dr. James F. Norris, assistant professor of chemistry, Massachusetts Institute of Technology, was unanimously elected an honorary member

of the Association. There being no further business the members listened to an address by Dr. Norris on "The Relation of Tellurium to the Periodic Law." By way of introduction the speaker called attention to the fact that recent authorities do not give the periodic law the prominence it once held, especially Ostwald, who devotes only six pages to it in his last book (Grundlinen der Anorganische Chemic), and Prof. A. Michael, of Tuft's College, who ridiculed the law in a recent lecture before the Northwestern section of the American Chemical Society. Neither of these chemists, however, proposed a substitute, and until that is done Dr. Norris believed that the law should not be abandoned. He then pointed out the value of this law to teachers as (1) a clearing-house of many facts of inorganic chemistry which are otherwise disconnected, and (2) an incentive to research. The importance of the latter point was brought out by quotations from Mendeleeff's "Faraday" lecture, delivered in 1889, twenty years after the law was promulgated. In 1869 the atomic weights of about twenty elements, which did not fit the classification, were changed by Mendeleeff, and chemists immediately began to redetermine the atomic weights and properties of these exceptional elements, especially beryllium, uranium and antimony. A search for the predicted elements was instituted and all three were found—viz., gallium, germanium and scandium. But of the twenty exceptional elements only tellurium today seems doubtful, and the speaker frankly said that he was led to study this element because of its doubtful position in the periodic classification, though the immediate incentive to the work was the outcome of an effort to secure a method for determining tellurium similarly to the method for selenium (devised by Dr. Norris and his colleague, Dr. Henry Fay). The tellurium at first used was purchased in Germany and was expensive, in fact, as expensive as gold. The present source is the "mud" deposited in the tanks used in the electrolytic preparation of copper. A barrel of this mud was obtained through the courtesy of the refiners in Baltimore, and when worked over yields about fifty pounds of tellurium at a slight cost. Dr. Norris and his colleague have devised a simple method for obtaining pure tellurium from the basic nitrate. The speaker gave an account of the various atomic weight determinations, especially those of Brauner, who used the bromide method but obtained discordant results. Another method involving the determination of carbon was also found to be faulty because the carbon determination is not sufficiently accurate for atomic weight work. This method gave results between 125 and 126, while Brauner's hovered around 127.6, and the oldest method, that of Berzelius, gave 128. A method utilizing native Japanese tellurium agreed with Brauner's result and indicates that there is no other element in tellurium. Recent work on the isomorphism of the compounds of tellurium, selenium and the platinum metals shows that isomorphism cannot be used as a test unless the water of crystal-

lization is the same in the compounds. Hence the question as to the proper group to which tellurium belongs is still open. The work is now being conducted by Dr. Norris and Dr. Fay at the Massachusetts Institute of Technology along the lines suggested by the work of previous investigators—viz., (1) isomorphism, (2) compound nature, (3) improved method of atomic weight determination. The fact that pure tellurium is at the disposal of these investigators indicates so far (1) that tellurium is elementary, contrary to the prediction of Mendeleeff as to its compound nature, (2) that the isomorphism of its compounds gives so far insufficient evidence, though considerable work has been done on this point, (3) that the real source of difficulty is in the constant source of error in the previous atomic weight determinations, since the results of several methods of other investigators do not agree. The work on isomorphism is still in progress, and a new method for the atomic weight determination is soon to be tried—viz., reduction of tellurium oxide by hydrogen and weighing both water and tellurium. This method checks itself, since the sum of the weights of tellurium and oxygen must be 100 per cent. At the close of the meeting the members inspected the apparatus for preparing pure hydrogen and other devices used in this work. Specimens of tellurium compounds were also examined.

The second address was by Mr. Walter O. Adams, head chemist at the Boston works of Lever Brothers, on "The Manufacture of Soap and the Recovery of its By-Products." He said about one billion pounds of soap are made annually in the United States, and New England used about twelve pounds per capita. A brief statement of the chemistry of washing and of the physical and chemical properties of soap was followed by an elaborate description of the raw materials used in making soap. Four alkalis are used—viz., the carbonate and hydroxide of sodium and of potassium, and these are obtained mainly from the Solvay works. The fats used are mutton and beef tallow, grease, cocoanut oil, cotton-seed oil, olive oil (rarely), and rosin. The last named, while not a fat, saponifies and is used in making many kinds of soap; it is not an impurity or adulterant, but is a legitimate material and gives the soap valuable properties. Specimens of these raw materials were circulated and were fully described by the speaker. The different kinds of soaps were then described and exhibited, including the ordinary hard soap, floating soap (which is merely ordinary soap having air "turned in"), and transparent soap (which is simply the residue from a solution of soap in alcohol, glycerine or syrup)—"no especial pains," said the speaker, "being taken to remove the glycerine or sugar." These soaps—floating and transparent—are no purer than other kinds, but "they please the public." The speaker then explained and described the processes of soap-making, paying especial attention to the usual method of boiling and the extensive treatment necessary to prepare a good soap. Illus-

trations were shown of the "crutches," "frames," "slabber," and "cutter," which are used to prepare the soap for shipment and use after it is made. He then gave a brief description of toilet, milled, remelted and other special soaps, stating naively that many sweet-scented soaps are inferior to the common laundry variety. Samples of crude and refined glycerine—the main by-product—were shown and the process of recovery explained. The address was exceptionally instructive and was given with a charming informality which added to its interest.

A vote of thanks was given to the speakers, and after a further inspection of the numerous samples the meeting adjourned.

Reported by LYMAN C. NEWELL.

BIOLOGICAL CONFERENCE OF THE MICHIGAN SCHOOLMASTERS' CLUB.

The Biological Conference of the thirty-sixth meeting of the Michigan Schoolmasters' Club held its principal session Friday afternoon, March 29, at Ann Arbor, Mich. About two hundred were in attendance. After the meeting was called to order by the chairman, Dr. F. C. Newcombe, some announcements made and the minutes of the previous meeting read and approved, the programme was taken up.

Professor C. E. Barr of Albion College read a paper on "Nature Study in the Schools," of which the principal points are here given: The weakness of the "classical education" was shown by experimental proof. It fosters dependence, while science education fosters independence, hence strengthens and gives power. The object of nature study is not to introduce science into the grades but to imbue pupils with the scientific method; to preserve and improve the natural powers through personal observation and inference rather than permit them, as now, to atrophy through dependence on authority.

Professor W. J. Beal of the Michigan Agricultural College next read his paper on "How Shall a Young Person Study Botany?" He gave reminiscences of his student time under the elder Agassiz and Professor Asa Gray, bringing out the well-known method of Agassiz in contrast to that of Professor Gray, who kept up the student's interest by telling him much that he could not see. He referred to the newer way of teaching, as outlined in his pamphlet, "The New Botany." He advocated explaining much to students during the first half of their course, and after that making them work out things more independently. Books should not contain figures that can be copied. A list of good text books was referred to and Ganong's "Teaching Botanist" was especially recommended to teachers. Courses in special studies were suggested. The idea was conveyed that even quite young persons can make original observations.

This was followed by a paper on "Outline for a Year's Work in Botany," by Miss L. Lenore Conover, Detroit Central High School, in which she said: "The first half of a year's course in botany should include a

careful study of the structure and habits of the most familiar plants, the phanerogams. Then, when the unaided eye has been trained to see and the mind to correlate facts, the second half of the year may be profitably devoted to the natural history of plants, with the object of presenting the relations of plants to one another and to other things in nature. This should include frequent reviews of phanerogams, field work and a study of representative types of cryptograms in which the compound microscope is indispensable."

The next paper was on the related subject, "Suggestions for a Year's Work in Zoölogy," by Miss Elonia Andre of the Detroit Central High School. The principal points were: "A course in zoölogy for high-school pupils should be of educational value aside from zoölogical information, and should give the pupil as broad an idea as possible of animal life. The pupil must realize that the variety of form and habit in animals is but an expression of their adaptation to conditions of life, and that the whole animal kingdom is an evidence of the fitness of things in nature, and that the structure of an animal depends upon the manner in which its functions are performed. To get this conception of animal life the subject must be studied from three points of view: Ecology, Morphology, Physiology."

A short paper on "The Value of Supplementary Experiments," by Mr. L. Murbach, Detroit, Mich., centered around two points: When experiments are properly understood and carried out they are valuable means for discipline and for acquiring new facts. More than one experiment should be given to lead pupils up to a fact, principle or law; these were called supplementary experiments.

Next followed a paper on "Science in the High School," by Miss Dora R. Palmer of the Lapeer (Mich.) High School. Her principal statements were: The development of the habit of observing correctly lies at the foundation of all scientific study. Experimental work when properly done is of great value in science teaching. All feeling of haste should be suppressed. Scientific training is the one great object to be gained in the teaching of science. It is more important that the pupil acquire power in his observation and reasoning than that his mind be stored with isolated facts. Study is one great whole and all studies depend upon one another. If we would get good work in the sciences, the foundations must be well laid in mathematics, English and drawing."

After this Dr. S. J. Holmes of the University of Michigan read a paper on "Recent Work and Theories on Fertilization of Animals." He said in part: "The principal experimental work on fertilization in animals has been carried along on two lines—fertilization of enucleated fragments of eggs and artificial parthenogenesis. Boveri in 1889 fertilized enucleated fragments and these developed into plutei which possessed only the characteristics of the pluteus (larva) of the male parent. Recently Dr. Loeb has made the remarkable discovery that the unfertilized eggs of the sea-urchin when treated for a time with certain salt solutions and then put back into

sea water develop into normal plutei. Later Dr. Loeb found that a mere increase of osmotic pressure, whether by the action of chlorides or of organic compounds such as sugar and urea, is sufficient to stimulate the ovum to develop. It appears that there is a variety of stimuli besides that afforded by the spermatazoön which may start the process of development."

The programme closed with a lecture on "Recent Work and Theories on Fertilization of Higher Plants," by Dr. J. B. Pollock, University of Michigan, which was illustrated with lantern slides. Dr. Pollock gave a review of the most important recent discoveries in the fertilization of higher plants, including the motile antherozoids of gymnosperms, the antherozoids of the sunflower resembling those of ferns, the fusion of one of the sperm-nuclei with the fused endosperm nucleus in several of the monocotyledons.

Each paper was followed by discussion of its practical bearings.

A short conference of Physiology teachers, separately held, was addressed by Dr. V. C. Vaughan, Dean of the Medical Department of the University of Michigan. In part he said: "I believe that the curriculum of every high school should provide for a course in physiology or hygiene, or both. This course should in part at least consist of laboratory instruction. It should contain enough anatomical knowledge to enable the student to know the location and relative position of the various organs of the body. The anatomical part might be demonstrated on a manikin or by the dissection of one of the lower animals. The student should have some information concerning the nature of food and food principles and the economic value of foods.

"The laboratory course should provide for the study of some of the more interesting species of non-pathogenic bacteria, yeast, molds, etc. This part of the course might be arranged so as to awaken great interest in the average student, and I am sure that correct information along these lines is quite as likely to prove of value to him in future life as that obtained from any other source. In these days, when there are so many followers of psuedo science, I believe that the teacher of science in the secondary schools has a great chance to benefit his race by giving to the boys and girls in his classes the general fundamental facts concerning the physiological functions of the body and the causation of disease."

After discussion of the practicability of teaching high-school physiology by the laboratory method, expense and apparatus of such a course, Professor O. S. Mast of Hope College gave his experience in "Physiology Taught by the Laboratory Method." Some of the chief points were: "The value of the laboratory method of teaching any subject that can be taught by this method is no longer disputed. Laboratory periods shorter than one and one-half hours are not satisfactory. High schools having a half year's work in physiology, with three laboratory periods a week and two recitations, could complete the work in any ordinary text book for high

schools by the laboratory method. Any fairly well equipped physical, chemical or botanical laboratory will contain nearly everything needed; while the organs of animals and different kinds of foods and other things required for study can be gotten at any butcher's shop and grocer's store for almost nothing, so that the actual expenses of the course will be very little. Fifteen to twenty-five cents per pupil would cover all expenses occurring from year to year. There is no longer any valid reason why there should not be a laboratory course in high-school physiology."

Reported by L. MURBACH.

PHYSICS CONFERENCE OF THE MICHIGAN SCHOOLMASTERS' CLUB.

The annual physics conference in convention with the Michigan Schoolmasters' Club was held at Ann Arbor on March 29 and 30, 1901. Its work consisted almost wholly of the exhibition of pieces of apparatus, their description and how used. The program was as follows: "The Inclined Plane," by Mr. De Forest Ross, Ypsilanti; "Modification of Whiting's Method of Determining the Acceleration Due to Gravity," by Mr. J. F. Selleck, Durand; "Coefficient of Expansion of a Gas at Constant Volume," by Prof. F. A. Osborn, Olivet; "Coefficient of Linear Expansion," by Mr. C. S. Cooke, Detroit; "Dynamical Measurement of Force," by Mr. N. H. Williams, Indianapoiis; "Foucault's Pendulum Experiment," by Mr. G. J. Burgess, Ann Arbor; "Reflection from Plane Surfaces," by Prof. E. A. Strong, Ypsilanti; "The Sonometer and Its Use," by Mr. C. F. Adams, Detroit; "A Simple Optical Bench," by Mr. F. R. Gaston, Ypsilanti; "Physical Laboratory Plans," by Messrs. Parrott, Ross, Adams, Cooke and Hawkes; "An Electrical Lantern for Laboratory Use in Optics," by Mr. H. N. Chute, Ann Arbor; "Rating a Tuning Fork," by Mr. F. L. Cooper, Manistee; "Downward Pressure in Liquids," by Mr. H. D. Minehin, Detroit; "Experimental Proof of Ohm's Law," by Mr. C. F. Adams, Detroit; "The Measurement of Candle Power," by Prof. F. A. Osborn, Olivet; "Measuring Focal Lengths," by Mr. A. O. Wilkinson, Detroit; "Modification of Kundt's Experiment," by Mr. E. H. Harriman, Ann Arbor; "Focal Length of Concave Mirror," by Mr. C. F. Adams, Detroit.

Great interest was taken in the work of the conference, as was shown by the large attendance and unabated attention throughout the long and varied program. It is expected that of the papers presented some will find a place in subsequent numbers of SCHOOL SCIENCE. At the business meeting H. N. Chute, of Ann Arbor, and C. S. Cooke, of Detroit, were re-elected chairman and secretary, respectively. A committee was appointed to confer with a similar committee appointed by the Michigan Academy of Science to take into consideration the question of making the Physics Conference of the Schoolmasters' Club the Physics Section of the Academy of Science. A committee was also appointed to devise ways and means of securing a prompt and satisfactory publication of the proceedings of the conference.

Reported by H. N. CHUTE.

NEW YORK PHYSICS CLUB.

The eleventh regular meeting of the club was held at the Erasmus Hall High School in Brooklyn on Saturday, February 16, 1901. After the routine business the election of officers resulted in the choice of the following for the ensuing year: President, J. S. Gibson, Wadleigh High School; vice president, J. M. Jameson, Pratt Institute; secretary, H. J. Weed, Manual Training High School, Brooklyn; treasurer, F. B. Spaulding, Boys' High School, Brooklyn. A report of the committee on apparatus was presented by J. M. Jameson. The following papers were read: "The Lecture Method as Applied in the Teaching of Physics," by Walter Barnwell, Columbia Institute; "Physics a Culture Study," by H. C. Cheston, DeWitt Clinton High School. After a generous lunch provided by the teachers of the school two instructive papers were presented by E. R. Von Nardroff. The first one was on "The Acoustical Analogue of Fizeau's Experiment on the Velocity of Light." A large reflector, two feet in diameter and ten-ft. radius, was used. A small whistle attached to a gas cylinder was the source of the sound, while a sensitive flame was used as an indicator of the recurring eclipses. The second demonstration was on "Diffraction Gratings for Sound." The grating consisted of a series of wooden slats, and the resulting phenomenon was analogous to that produced by diffraction gratings on light.

The twelfth regular meeting of the club met at the Peter Cooper High School on Saturday, March 23, 1901. After the routine business an elaborate and instructive report on "Current Events" was presented by M. D. Sohon. Among the laboratory devices presented were (1) "A Diffraction Grating of Simple Design," shown by E. R. Von Nardroff. This consisted of two short rods fastened together parallel about two inches apart and then wound around with fine wire. The wire was then soldered to the rods and one-half of it cut away so as to leave a number of the wires tightly stretched and close together; (2) "An 'Indexometer' by J. S. Gibson. This is given in full in another part of the magazine; (3) "A Calorimeter Jacket" by C. W. Harrington. This was made of felt commonly used to wrap around steam pipes; (4) "Illustrations of Capillarity by means of the Lantern" by W. F. Knox, Dr. Sachs' Collegiate Institute. A discussion followed upon the "Educational Value of an Experiment"; (1) "The weight of a Unit Mass of a Substance," by C. L. Harrington, A. L. Arey, and P. R. Dean; (2) "Latent Heat of Melting," by T. H. Currie, L. V. Case and M. D. Sohon. After a lunch tendered to the club by the teachers of the building the meeting adjourned.

Reported by R. H. CORNISH.

Correspondence.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

21. In a half-year course in botany, how much time should be devoted to the cryptograms, if one is provided with the necessary apparatus, and how much to a special study of the angiosperms?

22. To what extent should a pupil doing laboratory work be thrown upon his own resources in the overcoming of any difficulties of manipulation that may arise?

23. Why is it that students of the physical sciences do not usually know how to do the simplest algebraic work, even though they have had courses in algebra and geometry?

24. How can the poor mathematical work done by students of the physical sciences be improved?

25. What is a rigid and clear definition of the terms "lecture," "recitation" and "quiz," as used in high-school work in science?

26. What is the best material for a chemical table top—wood, glass, tile, soapstone or what?

27. What is the best material for a chemical table sink—lead (autogenously soldered), enameled iron, soapstone or what?

28. Does the presence of iron, as gas pipes, bolts, etc., in a physical table top interfere with the success of the experiments in electricity and magnetism given in the usual course in elementary physics?

29. Which are better—fume chambers on chemical tables where the student works, or at the side of the room?

30. The study of lower forms of plants in the laboratory suggests the need of a window case for the culture of mosses and ferns. The writer desires information from any one who has had experience in the use or construction of such a case, where mosses and ferns may be cultivated from the spores to the spore-bearing plants.

Detroit Central High School. L. LENORE CONOVER.

DISCUSSION OF QUESTIONS

13. *Should a teacher in a secondary school teach his own research work during a year's course in any science, to the detriment of the student's best broad knowledge of the subject?*

"To the detriment of the student's best broad knowledge of the subject," most assuredly not! But if the student is blessed with a teacher capable of doing research work and *actually doing it*, his enthusiasm and interest may be greatly increased by letting him get a hint of the methods, a peep at the apparatus in use. Too often a student believes that the writer of his text-book discovered or "made up" all that is in

it. The names tacked on to laws which he tries to commit to memory mean nothing to him. He has but a dim idea that science is being made more rapidly now than ever before. But if he is aware that his teacher is engaged in trying to wrest something out of the great Unknown, that there is an infinite amount of science yet to be made, his work becomes alive with interest. And if he can be led to believe that he, too, can after sufficient preparation attack the unsolved problems of science the quantity and quality of his work will be voluntarily doubled.

L. E. C.

15. *To what extent should teachers of one science be acquainted with the other sciences?*

Specialization is at once a bane and a blessing. Constant attention to one little field narrows one's views and throws this field all out of perspective. The teacher of a single branch of science often warps the minds of his students through his unwarranted magnification of his own specialty. On the other hand, however, it is only by unceasing study and observation of a single small part of nature that science advances. Nature as a whole is too vast for the comprehension of even a twentieth-century Humboldt, and man with wise ignorance is multiplying the number of what he in his impotence calls branches of science. A true teacher of science cannot but be attracted more by one of these branches than by the others, and he may count himself as very favored if he can give his time and attention to that one branch. He should not, however, as a true teacher, neglect to cultivate enough of an acquaintanceship with the other branches to recognize that while his own specialty is personally most interesting these other branches are fully as important. He should not elevate himself into a tower of specialism and look contemptuously down upon those who may choose to be interested in other phases of nature. He should particularly endeavor to impress upon his pupils the all-sidedness of things, and to widen their horizon. He should try to show how his own specialty is intertwined and interlaced with others, to point out that its boundaries merge imperceptibly into those of others.

17. *Are high-school pupils capable of taking lecture notes in science instruction understandingly and with profit?*

The main object of taking notes of a lecture is to get into a permanent form for future reference and study that which has been taken in by the ear. The shorthand reporter can reproduce the words of a lecturer, barring, perhaps, a few technical ones, without having any understanding of the subject before or after the lecture, and the only "profit" he may get out of it will be mostly of a pecuniary nature. Our students are not, however, masters of shorthand; very few of them, indeed, are masters of longhand, as regards legibility, punctuation and spelling. It is simply impossible for the average student to give in his notes anything like a

faithful transcript of what he has heard from the lecturer. Should, then, all note-taking of lectures be done away with? By no means!

The "lecture" in high-school work in science should deal with matters explanatory of or supplementary to the knowledge gained by student from the text-book or laboratory. It should be enunciated slowly and distinctly and the main points brought out very clearly. The student should not be allowed to attempt to note down everything that is said, but attention should be called to the matters to be noted and time should be given to note them down. This must not be a mere dictation exercise, but the student should write out in his own language, crude as it may be at times, the points which have been emphasized. Time need not be lost in thus giving the pupil a chance to use his pencil, for the lecturer may pause a minute or so to arrange apparatus for a demonstration or to put something on the blackboard. The ability to note down the argument of a lecture comes with practice, and plenty of practice is needed before the student becomes even moderately proficient. In these days when almost everything gets into print, whether it be worth it or not, the ability to take clear and accurate notes of spoken words may be regarded by some as of doubtful value. But values are relative. While the information in high-school work may be obtained from sources other than the teacher's lectures, yet proficiency in note-taking often stands one in good stead long after the student days are gone. The training of the powers of attention and concentration is also not inconsiderable in work of this kind. Note-taking has even more cultural than informational value.

It is an excellent plan to have the students prepare for a quiz on their notes after their memory of the lecture has somewhat faded. The student will then learn wherein he failed in his note-taking and where improvements can be made, and will be better prepared for the taking of notes in subsequent lectures.

L. E. C.

16. *How and to what extent should the history of a science be taught in an elementary course?*

One of the most difficult things in mental effort is to keep the attention fixed for some time on one point, especially if that point be hard to understand. And yet the more intense the attention the sooner the difficulties disappear. Attention is impossible without interest, and especially is this true in the teaching of certain parts of science. The successful teacher is the one who can get the "willing mind" from his students, and he can get this only in proportion to the interest and enthusiasm he can arouse. Experiments and demonstrations of themselves seldom fail to arouse and hold the attention, but science teaching cannot by any means consist of experimental work alone. How can we secure from our students this "willing mind?"

My experience has been that the introduction of historical matter

into lectures and recitations is productive of much interest. In assigning a lesson from a text-book I find that a brief anecdote or biographical note pertaining to the subject invariably whets the pupil's appetite and makes the preparation of the lesson less irksome. The subject takes on a humanistic aspect, and loses in a measure its "text-book aridity"; it becomes alive and fraught with human interest. Historical references in a recitation enliven even the dullest part of a subject.

The great difficulty in the way of a general use of the "historical method" is the lack of sources. There are only a few books on the history of science, and these are too high-priced for the students themselves to purchase. A desideratum would be the publication of a series of reprints of science classics at such low prices that pupils could provide themselves with them without much outlay. Until this lack of sources is supplied, about the only means of introducing the "historical method" into teaching is by lectures and occasional references to what historical matter may be at hand. The teacher should know the history of his science and should continually draw upon that knowledge in the class room. Apt historical references cannot be too numerous. The student learns from them not alone science, but history as well—and this history is the most important kind of history, a knowledge of which he will hardly get elsewhere.

C. E. L.

In the teaching of science the historical part should not by any means be neglected. It seems to me that our text-books do not lay enough stress upon the way in which discoveries have been made, upon the successive efforts that have been put forth to arrive at the truth, to clearly prove the laws of nature and point out their applications. A historical sketch has the advantage of making us understand how a discovery is made, what errors are to be avoided and what is the true method. The history of science is not alone written in honor of those who have contributed to its advancement; it is full of suggestion and inspiration for present generations, inasmuch as it marks the path thus far taken and points out the one we are to follow.

ALFRED MAURY.

We take this occasion of entering a protest against the ordinary text-book method of giving instruction in science. It would seem, from the reading of some books, that science had issued, all armed, from the brain of humanity. All that slow, patient work to which each generation contributed its efforts is lost sight of in a dogmatic exposition, which seems to be a revelation, to be hardly human and not to be subject to discussion. Science is thus separated from its natural tendency, which is the continual and intelligent discussion of all its parts.

M. DEHERAIN.

School Science

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A WORD OF CHEER.

The long vacation is over and another school year has begun. That this year may be one of joyful progress to all its readers is the sincere wish of SCHOOL SCIENCE.

Teaching, like all professional work, confers privileges and imposes obligations. One of its privileges is the opportunity to cease from routine work during the summer months; and one of its obligations is to utilize the benefits gained from this vacation.

While these lines are being written a refreshing breeze blows across the dancing waters of Frenchman's Bay, from the rugged hills of Mount Desert Island, off the coast of Maine. Bar Harbor lies at the foot of these hills, but its gay life has no helpful message for the teacher. The green earth, the blue sea and the bluer sky, however, send an eternal message. The earth bids us grow into a life of fruitfulness and symmetry, the sea says, "Let your life be active and harmonious," and the sky tells us to live to the fullest and be poised. You have heard these and other messages from the hill, the river, the lake, the mountain, the bird, the flower. Nature tells us, in so many and such varied ways, that vacation is the time to regain poise of body, activity of mind and consciousness of soul—the season for renewal of the whole being.

The summer vacation is an enviable privilege; but, like many privileges, it has an obligation. The resumption of regular duties should not, however, be accompanied with regrets. There should be no sighs for the past. The present is the time of power. Banish regrets. Let the memories of the summer be filled with joy, power and hope. We have had the privilege, let us, therefore, welcome the obligation. Let the power accumulated during the summer be a constant possession. The throb of Nature's heart

will be just as loud all the year as it was this summer. But, to hear it, we must transmute the peace and beauty of Nature into purpose, industry, hope and poise. The summer's pictures should never be dimmed by winter's labor. Let us, this year, be as firm as the mountain, peaceful as the lake, punctual as the tide, free as the bird, industrious as the bee, poised as the cloud and as beautiful as the flower, recalling ever the harmony and peace of all Nature.

SCHOOL SCIENCE ventures to present to its readers the following obligations, which we, as teachers, may meet if we accept them in unshaken confidence in our accumulated strength:

To remember that some good is in all pupils, and to crave that spiritual insight which shall detect the best; to lead all pupils on to higher attainments; to be patient, composed, forbearing; to be confident in the belief that the truth will ultimately triumph; to scorn error, deceit and all forms of falsehood; to forego sarcasm and injustice; to honor the body; to cherish daily communion with the soul; never to voice the thought of drudgery, routine or performance of duties rightfully another's; to sweeten others' labors with kind words and sincere greetings, and to gladden our own with a silent joy in the dignity of honest labor; to accept our remuneration, large or small, without envy, complaint, discouragement or covetousness, never forgetting that a teacher is a leader into the higher life—not a wage-earner merely; to work each day in unshaken assurance that fullness of peace, power and plenty comes to those who "see the heavenly vision undimmed."

L. C. N.

A PLEA FOR THE STUDY OF EDUCATIONAL PHILOSOPHY ON THE PART OF TEACHERS OF SCIENCE.*

BY N. A. HARVEY.

Head of Science Department, Chicago Normal School.

The results of the teaching of science in high schools have not been altogether satisfactory. There is a feeling, more or less prevalent, that the claims of science have been fully justified.

*Part of the President's Address before the Department of Science Instruction of the National Educational Association read at the Detroit meeting, July 11, 1901.

This finds expression in occasional articles in educational journals, in the recent great gain in the history and language courses over science in high schools and in the refusal of colleges and universities generally to demand science as a requirement for admission.

I cannot but feel that there is some ground for this coolness toward scientific subjects. My own experience would lead me to say that there may be some reason for the position that universities assume. I have recently had occasion to teach two classes a day in physics for three successive years. One was a class of high-school graduates, all of whom had studied physics. The two classes did identical work in the laboratory. For three successive years the tabulated records of the accuracy of data obtained in the laboratory showed that the class which had never before studied physics exceeded the accuracy of the high-school graduates in the proportion of about seven to three. It was a case peculiarly favorable for comparison, and I feel sure that the comparison is indicative of an actual condition in those classes.

The only explanation that I can suggest is that the teaching of the high-school graduates had been conducted under the influence of improper ideals; that the teachers were physicists rather than teachers; that, in other words, they needed to study educational philosophy and to get a rational knowledge of the content of the subject.

If there has been one advance in educational truth better demonstrated than another, it is that, in schools for general education, the knowledge of the facts acquired is not the chief value to be derived from a particular study. There is something more important than that, even in science. Just as the benefit derived from the study of algebra is not to be looked for in the answers to the problems that the student so laboriously solves, and the value of the study of Latin comes not from the knowledge of the historical facts that the pupil learns while reading the Latin language, so the value of the study of science does not depend upon the knowledge that the pupil acquires, but upon the power the student acquires while gaining that knowledge. In physics one set of exercises may be substituted for another without any disadvantage. It makes no difference whether one

class of animals is studied in zoölogy or another, provided other things are equal, and one set of exercises in chemistry may be a full equivalent for another series, yet it would be wrong to give both. In fact, there is recognized a fair degree of equivalency among scientific subjects—something in which they agree among themselves and differ from other subjects in their power to influence the mental habits of students.

In our work in zoölogy we study the structure and life of animals, but if my classes fail to see and to recognize the processes by which a general concept of a group is formed, if they fail to discriminate and compare, if they do not get into the habit of analyzing a specimen before them and of examining it part by part, if they do not learn what is involved in a logical definition, and, more than this, if they do not carry this habit of mind into every other subject in school, I feel that my work has been a failure, no matter how many or what animals they have studied, or how neat their notebooks, or how artistic their drawing.

In the determination of the laws of falling bodies if my classes fail to perceive the continual activity of a constant force by means of the effects, if they do not recognize the uniformity in the apparent diversity, if they do not recognize that here is a law, and how to perceive that law, if all that my students get out of the exercise is a knowledge that $s = \frac{1}{2} g t^2$, or, even worse, if they only learn that, in the laboratory, they can get the result that the text book says they can get, that the book has told the truth, and they have verified the statement, then I am not only a failure as a teacher, but I am a sham and a fraud, and my laboratory is part of a juggler's outfit, the principal purpose of which is to dazzle the pupil and the public. (This is a confession and not an accusation. In classical language, I have been there.)

If, in the determination of copper in copper sulphate, I fail to make my pupils see that the atoms of copper in the final compound which is weighed are the identical atoms with which we began; if the pupil is unable at any stage of the proceeding to point out where the atoms of copper are, then my work is a failure and the educational value of chemistry is either accidental or negative.

The results obtained from the pursuit of scientific subjects

under the influence of such a conception are likely to be very different from what they would be if it were believed that the knowledge of a few animal forms, or a few experiments in physics, were the purpose of scientific study. Of course, it is understood that a professional chemist or an electrician, or an investigator in biology, must know the facts of the particular branch of science that engages his efforts, and must set to work directly and explicitly for the purpose of learning those facts. But that is a phase of work that does not apply to high-school science.

I do not decry the learning of facts, nor would I set up for the pupil this more important but less tangible aim. By a pupil's knowledge of facts the teacher may test, in a measure, the clearness of comprehension, the awakening of power that the pupil obtains. But the teacher must look beyond the mere facts of the subject to the true content that furnishes the reason for its introduction into the curriculum.

The day has gone by when a knowledge of subject matter is considered sufficient preparation for teaching. How much knowledge of mathematics, higher and lower, is necessary to make a person a good teacher of fourth-grade arithmetic? How much knowledge of literature and language would guarantee success in teaching third-grade reading? How many university graduates would undertake a position in the grades of a city school with assurance of success? It is only a tempting of Providence that permits persons too poorly prepared to do grade work to teach in a high school. The application of pedagogical principles is as necessary to high-school work as it is in other grades, and university methods and models are not always capable of universal application.

The teaching of science is still in an inchoate and formative condition. There is no general agreement among teachers of any science, nor between different schools, concerning what shall be taught. Perhaps physics is the science which in high schools is best taught and most clearly defined. But physics in one school means a very different thing from what it does in another school.

The past few years have witnessed many attempts to formulate a course of study in science that shall constitute a point of departure for the teaching in high schools; something that high

schools can teach and that colleges can reasonably expect; something that shall be of value to all students who do not expect to go to college, and yet something that shall be a fair equivalent for the preparatory studies that are now required for entrance into college. This section of the N. E. A. four years ago appointed a committee for the especial purpose of formulating such a course. That committee, after much work, failed to agree, and, so far as accomplishing what it undertook to do, it is as if it had not been. No such course has yet been formulated, and I believe that no such formulated course ever will be generally adopted until it has its basis in the activities of the pupil rather than in the facts of science. A successful and meritorious course in science can never be made by addition nor subtraction nor substitution. No series of exercises can ever be presumed to give constant results. It certainly is not possible at the present time—and may never be possible—to state a course of science in terms of mental activity. But, until that is done, all of our courses in science must be tentative and unpedagogical. Until someone makes a study of the psychology of laboratory science, or shows just the phases of human activity that are most economically cultivated by each scientific subject, our teaching must continue to be more or less empirical and unscientific.

The recent recovery of classical subjects from threatened displacement has followed the recognition that the language of a people is the key to the thoughts of a people, and not merely a quantity of information, valuable or useless as the individual judgment considers it. The revival of history has come about from recognition of the fact that history is an expression of the life of a people, and not merely a catalogue of miscellaneous events. A similar change must occur in the teaching of science. The purpose and reason for science instruction must be sought for in the mind of the pupil, and not in the facts of the subject. For this aspect of the case I plead with all the earnestness of a decided conviction.

The greatest contribution of science to pedagogy has been the "scientific method." The "scientific method" is not a method of teaching, but it is a method of thought. It is a method capable of universal application. This universal method in all of its ramifications, should constitute the basis for all our courses of study in

science, and should determine the method and data of our teaching. I plead for a study of this universal method of thought, and for its exemplification in the things we teach. Then will there be no question concerning what shall be the course of study in science, no hesitation on the part of colleges to accept it as a college-entrance requirement, and no doubt concerning the value of science teaching.

THE AIMS AND PURPOSES OF MODERN WORK IN BIOLOGY.

BY FRANKLIN W. BARROWS.
Instructor in Biology, Central High School, Buffalo, N. Y.

The modern epoch in the history of biology dates from the epoch-making work of Darwin and the publication, in 1859, of *The Origin of Species*. For forty years Darwinism has been the chief dominating influence among biologists, stimulating not only fierce and prolonged controversy, but also patient and equally prolonged study and research. For the first decade after the promulgation of the evolution doctrine, the scientific world was arrayed in two hostile camps; Darwin and his followers fought, side by side, through the long campaign, until they compelled the unconditional surrender of every important stronghold of science. And then, the victory won, these comrades in arms began to emphasize their own individual creeds, and to wage controversies among themselves, which have developed for the last quarter century, until, today, the term "Evolution" stands for a heterogeneous mass of doctrine, in which we may discern at least three distinct schools, and a bewildering number of different shades of opinion. Thus, at the end of forty years, we are able to trace considerable progress in the evolution of an evolution theory. The *fact* of organic evolution is, practically, unquestioned. The lively controversies of today are concerned with the *methods* of evolution and imply a deeper and broader knowledge of the problems of life than was possible before Darwin's day.

While we recognize the important directive influence of Darwinism upon his own time and ours, we must not forget the bril-

liant achievements of many other workers who in earlier days laid the foundations of physiology, embryology, and nearly every other department of biologic work of anatomy.

But the number of these pioneers was small. The great majority of naturalists were content to spend their time in naming and classifying, according to rude and artificial methods, all sorts of living things; they overlooked more important questions while they sought out appropriate names for species and genera, and entertained the most absurd notions and fancies concerning life and its activities. This was about the state of affairs in America when Louis Agassiz was elected to the first professorship of natural history in Harvard College, in 1848, and began his career which was destined to transform the ideas and practices of every naturalist within reach of his influence. While Agassiz steadfastly opposed the advance of Darwinism, he maintained his position at the head of American zoölogists, because he was a born leader, a fascinating teacher, and an enthusiastic investigator. The leading American zoölogists of the present were trained by Agassiz, and reverently profess their debt to his personal influence; but his bias against the "phantom," as he called it, which Darwin and other naturalists were chasing, did not prevent his own students from becoming apostles of Darwinism and quoting his own brilliant discoveries in embryology against himself.

The stimulus to scientific activity which followed the launching of the doctrine of evolution, gave every biologist new work and more of it. The active workers had to verify the facts and observations which Darwin had been patiently and quietly accumulating for thirty years. Theorists had to subject the whole body of scientific knowledge to rigid re-examination, to revise their creeds, to affirm and re-affirm the foundations of biology. Every worker, from the specimen hunter to the professor and philosopher, found his occupation growing in importance from year to year. Scientific pursuits acquired a fascination and a popularity hitherto unknown. The army of scientists received recruits,—often very raw recruits they were,—at the expense of those institutions which still leaned toward the scholastic ideals of the Middle Ages. Colleges and universities shook off their conservatism and awoke to recognition of the new learning. Sci-

entific thought ran in new channels and expressed itself in a new and strange dialect.

It is the purpose of this paper to trace briefly a few of the many lines along which biology has developed, during this truly wonderful epoch, to state a few of the present aims and objects and to estimate the spirit of modern workers in this science.

The present status of biology would be quite impossible without the existence of laboratories. We owe the development of this idea mainly to Germany, where the model biological department, as much as fifty years ago, included at least five kinds of laboratories,—for botany, zoölogy, physiology, anatomy and pathology, respectively,—the latter science first receiving official recognition in 1849, when Professor Virchow was elected to the first professorship of pathological anatomy in the world. Nearly all of the biological laboratories deserving the name have arisen within the last twenty-five years; in America the best laboratories are all less than fifteen years old. But even this brief period has been sufficient for the development of the most exact laboratory methods and for the springing up of a new school of "laboratory biologists,"—men whose sole environment is the laboratory, and who believe that the questions of biology are mostly capable of being resolved into laboratory problems and solved by the aid of apparatus. The inevitable reaction against such narrowness has begun. Mere "section cutters" are falling somewhat into disrepute. An American physiologist* says:

> We need to realize in our modern laboratories that turning the crank of a microtome in and of itself has no more educational value, possibly not so much, as turning the crank of a grindstone. In fact, our theories of *laboratory research* and even of *laboratory instruction* in the brief period in which these have come into prominence have gone far astray. In drifting away from all considerations of human good and even common sense, our modern laboratory work is in the same danger of becoming an end in itself that sunk the old classification into a worse than imbecile waste of time.

Another leader† imagines Aristotle visiting us and asking the question: "Is not the biological laboratory which leaves out the

*Dr. C. F. Hodge, Clark University Decennial Volume, p. 113.
†Dr. W. K. Brooks, Foundation of Zoölogy, p. 41.

ocean and the mountains and meadows a monstrous absurdity?"

In view of these criticisms it is very gratifying to know that within recent years we have established a number of laboratories which conform much more satisfactorily to the rational type suggested in Aristotle's question. Our seaside and lakeside laboratories and our agricultural experiment stations and fish hatcheries are contrived to bring the investigator into the closest possible intimacy with the lives and surroundings of the plants and animals which he observes and subjects to experiment. The marine biological station at Naples was at once the pioneer and the model in work of this kind, and its successful establishment was followed by the opening of one or more marine laboratories in nearly every civilized land, followed somewhat tardily by inland laboratories on the shores of lakes and rivers, beginning with Switzerland. In America the seaside work begun so auspiciously on the island of Penikese by Louis Agassiz, was resumed after an interim of several years by the founding of the Marine Biological Laboratory at Woods Hall in 1888. It is no exaggeration to say that since this time the Woods Hall laboratory has been the biological center of America, although five or six newer laboratories have sprung up at different points on our coasts. The number of fresh water biological stations in America is considerable, many of our state universities taking the lead in this movement. In all such laboratories the work of teaching is subordinated to the more important functions of investigation and experiment. The U. S. Fish Commission and the Fish and Game Commissions of many of the states maintain similar stations where the purely economic aspects of biology receive the chief attention.

Not alone in the biological stations, but in the Agricultural Experiment Stations the laboratory men are learning to go out of doors for their facts. Our government is much more generous to these agricultural institutes than to the fish stations and the results have more than justified the expense. Indeed it may be said with truth that the American government leads the world in the practical study of applied biology, especially in economic entomology. Our agricultural colleges and stations were, most of them, established as the result of the acts of Congress known

s the Morrill Act of 1862 and the Hatch Act of 1887. We now ave fifty-six experiment stations in all, employing 678 officers.)uring the last ten years the number of these stations has in-reased about 20 per cent, while the cost of maintenance and the umber of men employed has increased 70 per cent.* The re-ılts reached during the last quarter century have been of inesti-ıable value. In England they have a very expressive term for ıe scientific study of soils and crops; they call it "manuring with rains." In order that we may know whose brains have been ıanuring the farms of the United States, we are told that in 1898 ut of a total of 669 officers on the staffs of our experiment sta-ons, 305,—or more than 45 per cent,—gave instruction in col-:ges. Thus, our government has indirectly interested itself in :etting the "laboratory naturalists" out of doors. The general ffect upon the biologist of such laboratories as we have been lescribing is well expressed by Professor Forbes, the state biolo-;ist of Illinois, who says: "It is, in fact, the biological station, visely and liberally managed, which is to restore to us what is)est in the naturalist of the old school, united to what is best in he laboratory student of the new." He might have added that he work of these institutions is giving character to the teaching n all our colleges and many of our secondary schools,—is, in fact, ;etting the pace of biology in this country.

This out-of-door activity, led by those investigators, who :evolt from the notion that all the world can be sliced up and ;een through the microscope, has given rise to a new branch of)iology, which they have christened ecology, and which deals with the relations of living things to each other and the sur-·ounding world; their modifications and adaptations in response :o their environment. It is a branch of biology which takes us :o the homes and haunts of life, back to nature herself. It is)ffered to the student as the newest novelty in biology and is ıighly recommended by doctors of philosophy as an antidote for :he more sedentary pursuits of the laboratory.

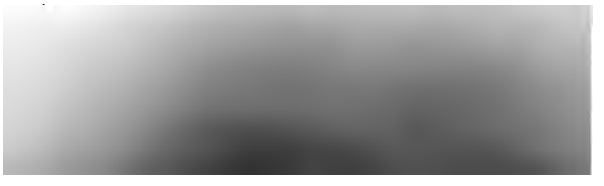
The fresh-water biologists have also evolved a new sub-sci-:nce, limnology, which is not yet defined in the dictionaries, and which applies to the study of lakes and their inhabitants.

*Year Book of the Department of Agriculture, 1899, pp. 513-548.

sound pedagogical doctrine for the elementary and secondary teacher, it is thought these exercises may even lay claim to soundness in this particular.

Finally, it is hoped that others may find such exercises as these may suggest as stimulating, teachable and educative, in actual class-room work, as the writer has found them; and that the common notion that expensive apparatus and elaborate library facilities, on the one hand, or pure text-book study, on the other, are not the only alternatives open to the teacher of elementary astronomy who believes in the efficacy of scientific methods of imparting truth in the class-room.

The first six experiments are intended to give the beginner in astronomical measurement an idea of the way he may use his hands and a few sticks and strings and other ordinary auxiliaries to secure better and more accurate results than can be obtained by mere guesses at the magnitudes he must now deal with. Their value consists chiefly in clearing away the confusion which confronts the student when he first comes to the necessity of estimating and measuring angular magnitudes, and in clarifying his views as to the nature of the problems in measurement which are demanded in astronomy. These exercises will enable the novice to convert his *guesses* into *estimates,* and lead him to feel the need of the still higher accuracy which is attainable through the construction of such auxiliary apparati as follow. The measurements involved in these exercises are to be executed upon familiar objects, thereby eliminating the element of mystery, which too often troubles the beginning student when he first has to do with celestial objects and more refined and complex instruments. The next two exercises seek to establish, experimentally, by measurements on familiar objects, certain fundamental laws, on which later and more difficult exercises depend. In short, the first seven exercises are merely intended to orient the student with reference to the problems which follow.



EXPERIMENT I.

To find the length of one's pace.

(a.) Stake out a square acre, on level ground, and, pacing its perimeter and diagonals two or three times, determine the length of your pace.

(b.) Measure with the tape, and stake out, on a 5 per cent or 10 per cent grade, a line of 100 feet or 200 feet, and step it not less than five times both upwards and downwards. Determine the length of pace both upwards and downwards, and compare the lengths with each other and with the lengths for level ground.

EXPERIMENT II.

To find the angle of the fingers and hand held at arm's length.

(a.) Extending your arm horizontally in front of your face, measure the distance from your eye to the palm of your hand, the arm being fully extended and the hand being bent at a right angle

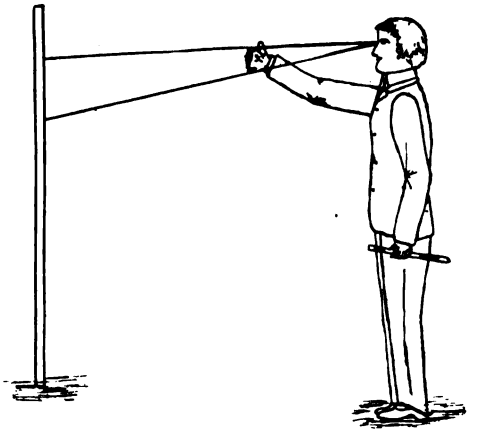


Fig. 1.

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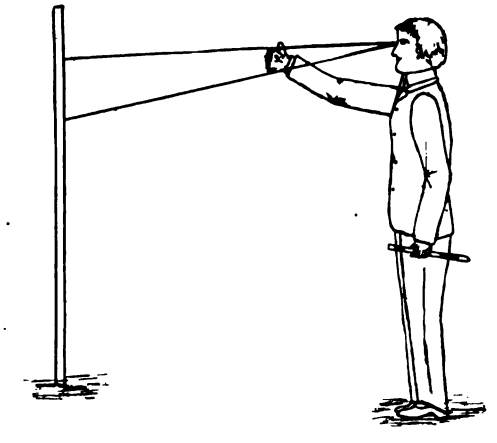


Fig. 1.

to the axis of the arm. Measure now the breadth of the individual fingers, their combined breadth across the joints just beyond the knuckle, and the breadth of the palm across the knuck-

les. Construct on paper isosceles triangles having the hand and separate finger breadths as bases, and all having the distance from the eye to the middle of the palm as altitude. Measure the vertical angles of these triangles with a protractor, and keep a record of their values for your own hand and arm.

(b.) Set a flagpole or stick behind your hand, and at a measured distance from the eye, and measure the spaces just covered by your separate fingers and palm on the pole. Using these as bases, construct to any convenient scale isosceles triangles as before. Obtain the angles with a protractor, or trigonometrically as in (a).

[NOTE: Experiments I. and II. will furnish convenient standards for obtaining estimates of lengths of lines, distances to remote objects, and sizes of angles which will be considerably better than mere guesses.]

EXPERIMENT III.

To erect an approximate perpendicular to a given line from a given point within the line.

(a.) Let the observer stand on the given line (usually marked by two stakes stuck in the ground) at the given point, and face the direction whence the perpendicular is to proceed. Let him then extend both arms horizontally, the one toward the right and the other toward the left, holding the thumbs upward for sights. Holding the neck straight, in continuation with the spinal column, let him now turn his head, first toward the right and then toward the left, sighting in the right thumb on the right stake, then the left thumb on the left stake. This done, he will turn his head squarely to the front, then carry both arms horizontally to the front at the same time, until the palms are together, with the thumbs extended upward. Sighting over the thumbs, he now indicates to an assistant where to stick a stake in the line of his eye and thumbs, or notes where this line touches some more or less distant object. This point, which must be marked, and the point over which the observer is standing, will determine the required perpendicular. This method is used by engineers in rough preliminary surveys.

(b.) Test the accuracy of the right angle just constructed, by the 3-4-5 or 6-8-10 method of turning right corners, used by carpenters and builders.

(c.) Test also by means of the principle of equal oblique lines.

(d.) Repeat method (a) until some degree of accuracy and certainty is secured.

Experiment IV.

To find the slant of the sun's rays to the plane of the horizon.

(a.) Holding a stick vertically, measure its height and the length of its shadow, and plot, to any scale, the measures on two

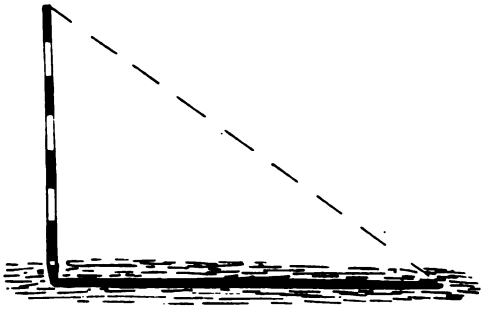


Fig. 2.

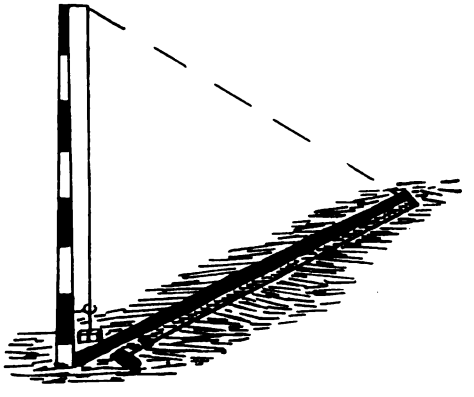


Fig 3.

lines drawn perpendicularly to each other. Connect the ends, and measure with protractor the angle opposite the line representing the height of the stick.

(b) With the aid of a plumb-line held at the top of the stake and passing through a narrow ring near the bottom the stake may be held more nearly vertically. The plumb-line may consist of a brickbat tied to a string.

(c.) Perform the experiment with the plumb-line supplied with a bead (a piece of cork) sliding with gentle friction up and

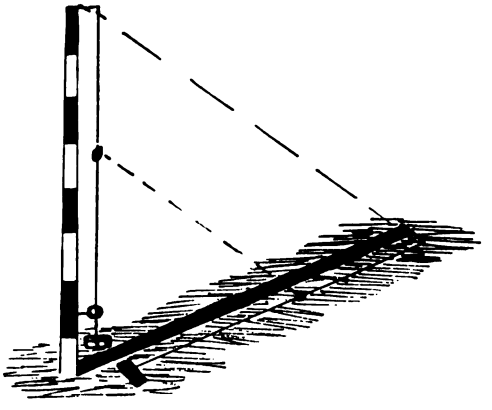


Fig. 4.

down the string. Measure and use the height of bead and distance of its shadow from point directly under the bob (brickbat) as height of stick and length of its shadow were used above.

[NOTE: These experiments will furnish more accurate values for the angle, if treated trigonometrically, as may be done by older students.]

EXPERIMENT V.

To find the height of a tree, building, or other object by the length of its shadow.

(a.) Measure the lengths AE and CD of the shadows of the building and of the stick. Then if ABEH, we have

$$h : CF = AE : CD, \text{ or, } h = \frac{AE}{CD} CF.$$

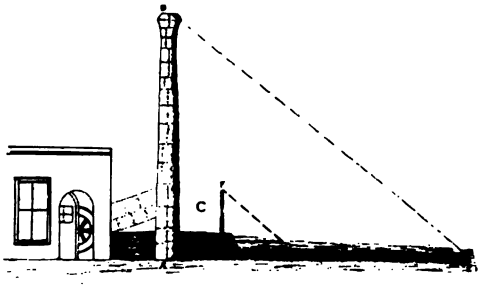


Fig. 5.

Experiment VI.

To find the horizontal, or oblique, dimensions of an inaccessible object, distances being known, and conversely.

(a.) Place yourself approximately (by guess) in the perpendicular at the mid-point of the dimension (DE) to be measured, and, setting a stake at your station (A), get behind it and line in with the ends of the dimension to be found at distances 10 feet, 20 feet, or 100 feet from this station two other stakes

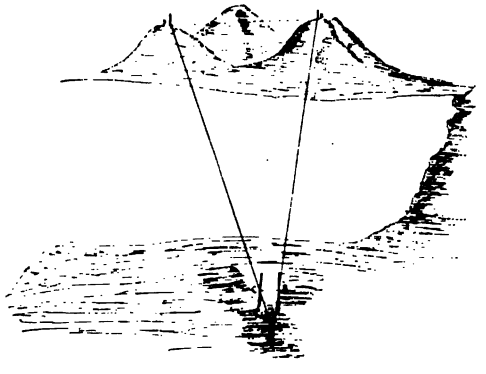


Fig 6.

(C and B), and measure the distance, BC, between these two stakes. The distance from your station to the ends of the line DE being known, the proportion of (a) Experiment V. furnishes the solution; thus h:BC=AB:AD.

[REMARK: If the dimension is unknown, the distances are thus obtainable.]

(b.) This experiment may also be executed with an extemporized plane table, consisting of a flat-topped camera tripod, to the top of which a light drawing-board is screwed, the alidade (ab., Fig. 7), being made of a foot rule carrying two vertical needles for sights. The leveling up may be done with a 25-cent level to be had of any hardware dealer, or with a home-made level consisting of a small glass vial nearly filled with alcohol, the bottle being countersunk in a block of wood.

(c.) For an oblique dimension, by sighting along the top of the board (B) the plane of this board may be brought into the plane of the line to be measured and the line of sight to the mid-

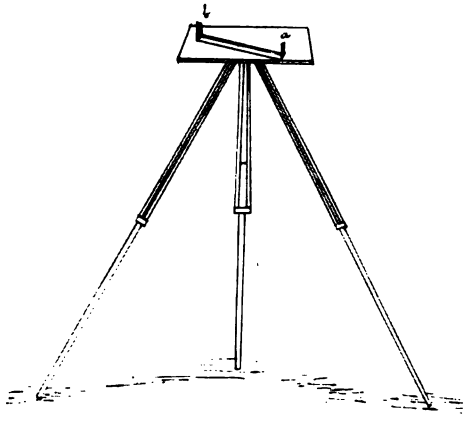


Fig 7.

dle of the board by adjusting the lengths, or positions, of the tripod legs. The sighting with the alidade and measuring are then carried out as in (b).

(*To be continued.*)

AN IMPROVED FORM OF KUEHNE'S ARTIFICIAL EYE.

By E. P. Lyon.

Assistant Professor of Physiology, Rush Medical College, Chicago.

The apparatus devised by Professor Kühne, of Heidelberg has long been one of the best means of demonstrating the refraction phenomena of the eye. However, the instrument as constructed by foreign makers is so clumsy and expensive as to preclude both its use by the individual student and, in many cases, its presence as part of the scientific equipment of schools and colleges. The number of phenomena which it illustrates is also quite limited.

Desiring to introduce the instrument at Rush Medical College, Dr. Zoethout and myself have devised several improvements, and with the assistance of the Geneva Optical Company have put into use in our laboratory a modification of Kühne's apparatus which leaves little to be desired. It is well adapted for individual experimentation in students' hands and makes clear both the refraction phenomena of the normal eye and also various abnormal conditions and the proper corrections for them.

The basis of the instrument consists of a rectangular box about ten inches long, five inches high and four inches wide. The box is open at the top. One end and one side are of glass. At the other end is the cornea represented by a convex glass. A series of diaphragms which slip in back of the cornea represent the iris and various sizes of the pupil. Lenses are provided which can be suspended from the top of the box behind the diaphragm and represent the crystalline lens. There is a lens for near and one for far objects. The retina is represented by a ground glass plate, which also hangs from the edges of the box and may be adjusted to any position. All the optical parts are made in spectacle or "trial case" sizes, thus reducing the expense very considerably.

When the "eye" is to be used, the box is filled with distilled water to which a few drops of 1 per cent eosin solution are added. The fluorescence thus given to the water enables one to trace

the rays of light, to see the bending of the rays at each refracting surface and to follow them as a beautiful cone to a focal point. The water in front of the crystalline lens represents the aqueous humor, and that behind the vitreous, both of these in the normal eye having the same refractive index as water.

The artificial eye is best used in a partially darkened room. The object viewed is represented by a lamp, preferably an incandescent electric or Welsbach. A cross or other figure placed before it is an advantage. When two objects are needed at one time, one near, the other farther away, a candle represents the second. For experiments in which the object is moved, candles or small kerosense lamps are more satisfactory than the Welsbach.

The following phenomena were demonstrated by each student in my laboratory:

1. *Images.* The inverted, real image on the retina. The comparative size of image when object is near and far. Comparative movement of object and image.

2. *Accommodation.* The change in the crystalline lens necessary to make a sharp image when the object is brought nearer. The "near" and "far" points of accommodation. Blurring of image when object is too near. The blurred image of a distant object when the eye is accommodated for a near one, and *vice versa.*

3. *Function of the Iris: Spherical Aberration.* The comparative sharpness and brightness of images of near or far objects when using large or small diaphragms, or no diaphragm at all. A ring diaphragm is provided by which the light may be shut out from the center of the lens and allowed to pass through the outer portion. The change of focus thus effected and "circles of diffusion" can be demonstrated.

4. *Refraction.* The bending of the rays at the cornea and at the lens. The convergence of the rays to a focus and divergence after passing it. The comparative refractive power of the two lenses.

5. *Scheiner's Experiment.* A special diaphragm with two

holes is provided for this experiment, and all details of it can be illustrated.

6. *Far Sight.* The eye is shortened by moving the retina forward. A clear image of a distant object can be obtained, but not of a near one. The eye is provided with a lens holder in front of the cornea, and proper lenses ("trial-case lenses") to correct this and other anomalies of refraction are supplied.

7. *Near Sight* is illustrated and corrected in similar manner.

8. *Astigmatism.* A special asymmetrical "cornea" is provided, which may be substituted for the "normal cornea." The cone of rays as seen from the side will now be found to come to a different focus from that seen from above. This is beautifully demonstrated. To focus the upright of a cross the "retina" must be placed (according to the axis of astigmatism) either behind or in front of the point at which the horizontal bar is focused. Assuming that either position of the "retina" is the normal, lenses are provided for the corresponding corrections; and the lens holder is graduated for the determination of the angle at which the axis of the cylinder must be placed. Astigmatism combined with myopia or hypermetropia may be illustrated and corrected.

9. *Vision without Lens.* The condition when the lens, as in case of cataract, has been removed. Improvement of vision by a very small diaphragm (pin-hole image) and by use of lenses.

10. *Purkinje-Sanson Images.* The images formed by reflection from the surfaces of the lens and cornea. The effect on these of accommodation.

11. *The Function of the Cornea.* It may be shown that the cornea alone can furnish an image by placing the "retina" far back. A further illustration is made as follows: A glass plate with a rubber washer is held against the mounting of the "cornea" in front; and the space between it and the "cornea" is filled with water. The "cornea" is thus thrown out of function. The image is blurred, the focus being back of the "retina." This illustrates the imperfection of vision under water.

By using two "eyes" side by side, many of the phenomena of binocular vision can be demonstrated. The retina can be marked

oft in squares with pencil or India ink, and the theory of identical points can be illustrated. Double vision from crossed eyes is easily made clear to the student. These experiments were omitted in my laboratory only from lack of time.

Doubtless other experiments could be devised. I can only add that my students have been so much pleased with the "eyes" that many of them have put in extra time studying the phenomena which they illustrate.

A NEW MACHINE FOR ILLUSTRATING THE LAWS OF UNIFORMLY ACCELERATED MOTION.

BY W. H. HAWKES.

Instructor in Physics, Ann Arbor (Mich.) High School.

It is hardly necessary to recount to teachers of physics the difficulties encountered in an attempt to illustrate and demonstrate the laws of uniformly accelerated motion, and to do it so that the results will be at all quantitative in character. These difficulties are too apparent by experience to need discussion. We shall not take time nor space to review the many devices and methods, already too well known by their aggravating futility, employed to overcome these difficulties, but rather shall present a new and effective device for solving this perplexing problem and demonstrating the laws of falling bodies with a degree of accuracy that compares favorably with that of other standard quantitative problems in experimental physics.

The value of the results obtained by any method in solving a physical problem depends in a large measure upon the extent to which we are able to eliminate sources of error. In the problem of uniformly accelerated motion the two great sources of error with which the experimenter must contend are friction of the moving parts and the personal equation. Friction may be reduced by the use of very delicate bearings to a quantity that will be hardly apparent in results. The personal equation is necessarily large, and is not so easily disposed of, even in cases where the experimenter has trained senses and good judgment; but the

most trained ear or eye is not sensitive to sound or sight beyond the sixteenth of a second; hence the space traversed by a body (which is considerable at its greatest velocity) during this time is enough to render the observed value doubtful and uncertain. The use of the inclined plane involves the errors arising from the observer's estimates of the coincidence of two dissimilar sense perceptions; either the click of the clock and the crack of the rolling ball, as it strikes the ruler held across the plane, or the position of the moving body at the instant the click of the clock is heard. In either case the demand upon the untrained perceptions of the high-school student is too great, and the consequent errors of observation render the results of little value. The old form of Atwood's machine involves nearly all the sources of error manifest in the inclined plane, so that only approximate results are obtained from its use, while the large amount of time consumed in securing sufficient data is in itself a fatal objection to its employment in laboratory classes enrolling many students. For these reasons this useful and instructive experiment has, in many laboratories, been supplanted by problems of lower importance, because they require less experimental skill and furnish more accurate results.

An attempt has been made in the instrument here presented and herein described to secure results that will be not only independent of any error in judgment and sense perception, but will also render it possible to obtain a continuous record of distances traversed during corresponding intervals of time.

This instrument may be called a self-registering Atwood's machine. Its essential parts (Fig. 1) are a marking device, *M*, controlled by a pendulum, *P*; a wheel, *W*, hung on delicate bearings (jewel) carrying upon its rim a belt of tissue paper ribbon, *T*, upon which the record is to be made, and to which are attached the counterpoised masses, *C C*, and overweight, *O*.

The pendulum is first adjusted by leveling screws in the base of the instrument so that the needle point at its lowest end stands when at rest exactly in the center of the mercury globule, *H*, through which it passes on closing the circuit, *P C*, controlling the recorder, *M*.

After the recorder has been adjusted, a switch, *S*, connects

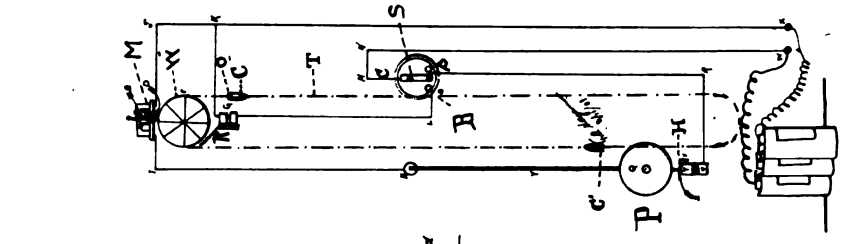


Fig 1.

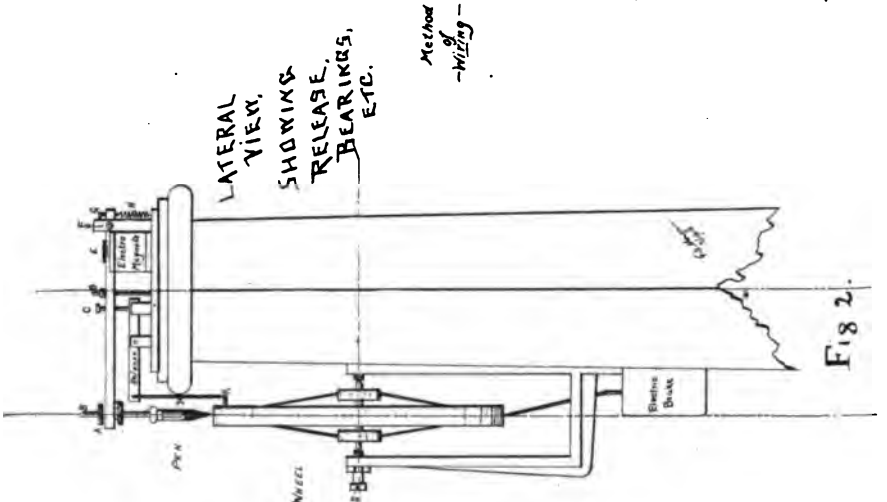


Fig 2.

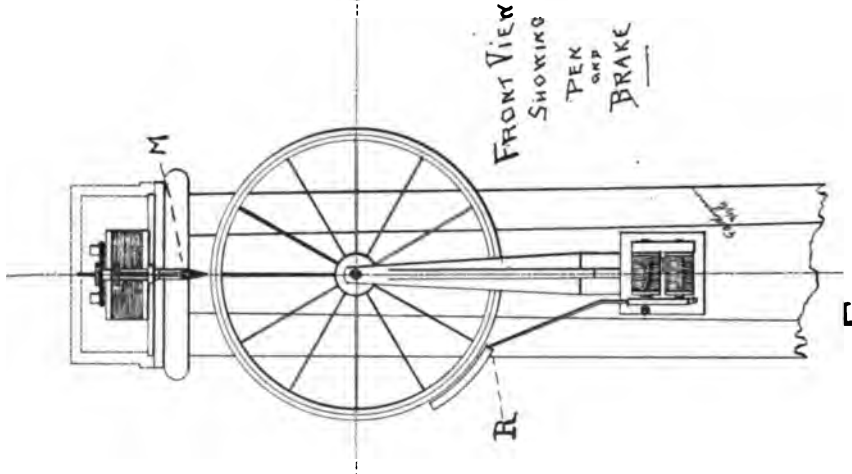
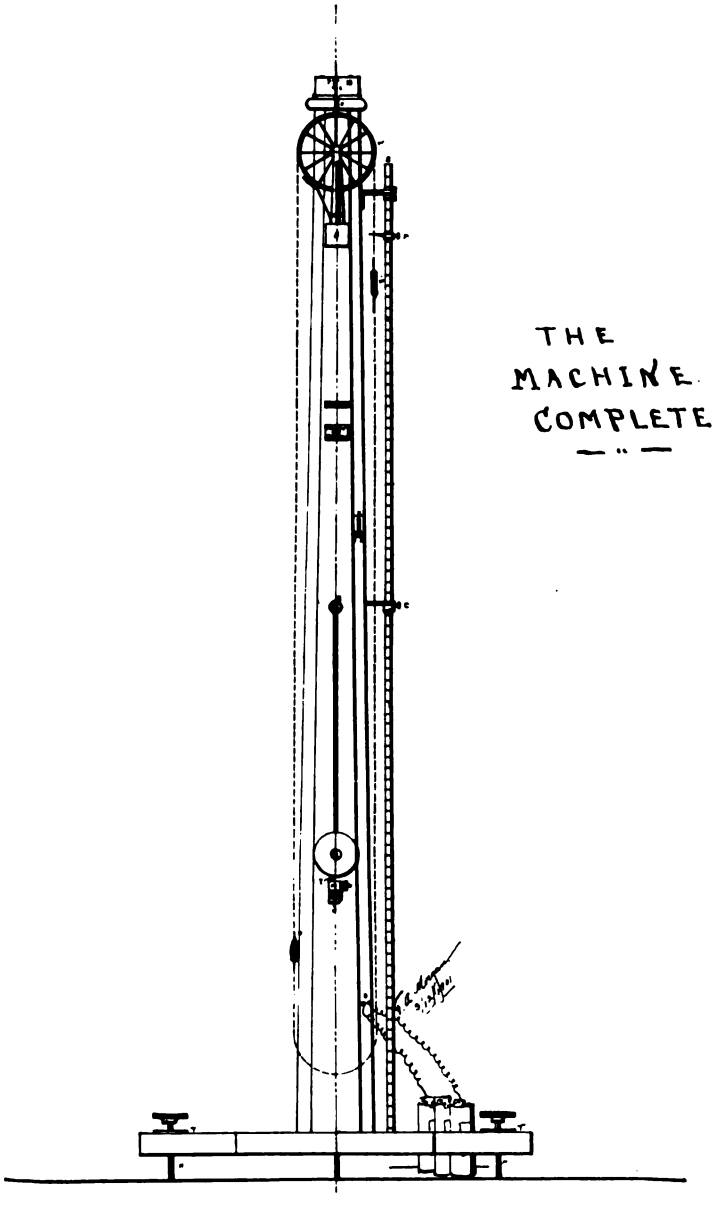


Fig 3.



THE MACHINE COMPLETE

the flattening of the earth's figure at the poles might be determined by a comparison of the two measures. It is unprofitable to discuss the results of these two expeditions which were superseded by that of Delambre and Méchain. We will now consider the establishment of the metric system.

On the 8th of May, 1790, Talleyrand induced the National Assembly to

Prince TALLEYRAND (1754-1838).
From an engraving by Gerard.

adopt a decree paving the way for uniformity of weights and measures. This decree concluded by naming a commission composed of Borda, Lagrange, Laplace, Monge and Condorcet. They rendered a remarkable report on March 19th, 1791, pointing out what they considered the three possible bases of a rational system, viz.: First, a pendulum beating seconds; second, a quadrant of the equator; and third, an arc of the meridian. They eliminated the first because it introduced the element of time, and the second because of the difficulties attending its determination, and selected the third because it was capable of accurate measurement.

unit will give the acceleration for each unit. (One-half of the average acceleration is taken as a corrected first value for S, or total distance fallen the first time unit. This must be very exact as all the other values are compared with it).

SECOND METHOD.

By this method any error in measurement of total distances or errors due to inequalities of friction is cut down by the constantly increasing denominator in the formula.

The accelerations thus determined are then used in computing the distances fallen during successive time units and also in computing the velocities as described below.

1. S, or the total distance found, as described in the first method.

2. S', or distance fallen each second, is found by taking for the first value, $\frac{1}{2}A$, and for each succeeding value adding in succession the accelerations, A, to the first value.

3. Acceleration is determined by substituting the value of S in the formula

$$A = \frac{2S}{T^2}$$

4. The velocity is determined by taking the sum of the accelerations successively.

5. To show that the total distance varies as the square of the times, divide each total distance by the square of the corresponding time; this ought to give a constant quantity if the law is true.

6. To prove that the velocities vary as the time, divide each velocity obtained above by the velocity at the end of the first time unit. Then, since A is constant, V varies as T.

7. To show that acceleration is constant, divide each acceleration by the average acceleration.

8. To show the ratio of the distances traversed by the falling body during the successive units of time, divide the distance traversed during each unit by that traversed the first unit.

To make this still more clear, a set of data is worked out in full below. These values are the results as actually taken from

a single ribbon. The values of the different quantities are derived as described in the foregoing directions:

S=total distance.

S′=distance fallen during each time unit.

A=acceleration.

V=velocity.

The average of $\frac{1}{3}$ *A* is taken for the value of the first *S*.

TIME	TOTAL DISTANCE	DISTANCE EACH SECOND	VELOCITY AT END OF TIME	ACCELERATION
Units	$S = \frac{1}{2} a T^2$	$S^1 = \frac{1}{2} a (2T-1)$	$V = AT$	A = Constant
1	3.58 cm.	3.57 cm.	7.10 cm.	7.14 cm.
2	14.26 cm.	10.70 cm.	14.29 cm.	7.13 cm.
3	32.13 cm.	17.84 cm.	21.49 cm.	7.14 cm.
4	57.20 cm.	24.99 cm.	28.60 cm.	7.15 cm.
5	89.38 cm.	32.13 cm.	35.71 cm.	7.144 cm.
6	128.67 cm.	39.27 cm.	Mean	7.142 cm.

Ratios of these quantities to each other:

Ratio of S $S \propto T^2$	Ratio of S′ $S' \propto (T-1)$	Ratio of V $V \propto T$	Ratio of A A = Constant
1.000	1.000	1.000	1.000
3.994	2.999	2.012	0.998
9.000	4.998	3.026	1.000
16.020	7.000	4.028	1.001
25.036	9.010	5.029	1.000

The value of the force of gravity is easily computed from the acceleration, the time of the pendulum being taken and the moment of inertia of the wheel being known. The latter is computed at the time of the construction of the wheel. The ribbons are weighed and masses of the counterpoise weights and the overweight found. Then by substitution in the formula below, the value of *g* is found.

$$g = \left(\frac{W + W' + \omega}{\omega \, l^2} \right) a$$

W=mass of counterpoise weights, ribbon and clamp.
W′=the wheel constant for that particular machine.
u = the overweight.
a = the observed acceleration.

AN EXPERIMENT TO ILLUSTRATE CHEMICAL EQUILIBRIUM.

BY FELIX LENGFELD.
Professor of Chemistry, University of Chicago.

The subject of chemical equilibrium is of such fundamental importance that it should be taught the beginner as soon as possible. It is certainly less difficult to understand than much that one sees in every elementary text-book of chemistry. The student who has a working knowledge of the underlying ideas will find it useful in his later work, whether it be in chemistry or in subjects extremely remote from chemistry. A number of experiments illustrating chemical equilibrium have lately been collected by Noyes and Blanchard,* and deserve the careful attention of all teachers of the subject. To this list I desire to add the following experiment which, on account of its simplicity, is especially adapted to the needs of the secondary school:

Three explosion eudiometers (Hofmann's are best, but not essential) are connected so that the same series of sparks may be sent through all. In the first I put about 10 *cc.* of dry ammonia over mercury; in the second exactly twice as many *cc.* of a mixture of three volumes hydrogen and one volume nitrogen, also over mercury; and in the third some of the same mixture of nitrogen and hydrogen over dilute sulphuric acid. Sparks are now passed and in the course of a few hours the volume of gas in the first two is the same, showing that whatever be the initial stage, the final is identical. In the third eudiometer the liquid will rise to the platinum ears, showing that as fast as ammonia is absorbed, more is formed, and that the action is complete, because there is a tendency to a state of equilibrium, and not in spite of this tendency. As the experiment with the quantities given takes several hours, it is best to begin it one day and show the results the next, or to diminish the volumes taken.

*Jour. Am. Chem. Soc., XXII., 726 (1901).

by high-school teachers, and there is a simpler method which I have always found effective, namely, that of decapitation. The inexperienced teacher can do it more easily than he can destroy the brain with a needle. It is simply necessary to make one sharp clip with a stout pair of scissors through the region of the ear, and rolling the frog in a moist cloth, fasten two toes over a notch in a thin piece of board that will fit on the stage of the microscope. After the class had seen the circulation in the web of the foot, the frog may be opened and the beating heart demonstrated.

L. M.

Carbon Monoxide Ceases to be Poisonous when the animals breathing it are confined in oxygen under two atmospheres' pressure or air under ten atmospheres, even though 6 per cent. of carbon monoxide is present, while under ordinary pressures animals die when only 0.5 per cent. of the monoxide is present. If the animals confined in the vessel containing the mixture of oxygen and carbon monoxide be taken out into the free air. they die at once; but if the mixture is very slowly replaced by pure air. the animals survive exposure to the free air. The antidote then, for cases of poisoning by carbon monoxide, would seem to be the breathing of compressed oxygen.

Compt. rend. CXXXI, 483.....A. Mosso

CHEMICAL.

Oxygen from Sodium Peroxide.—When small quantities of oxygen are wanted for certain demonstrations (as the endiometric determination of the composition of water, etc.), recourse is commonly had to a store of the gas in a gas holder, or potassium chlorate is heated in a small retort. Gas holders are, however, so bulky as to take up a good deal of room on the table, and the heating of potassium chlorate requires considerable attention to get a flow of gas at all uniform. The action of water on sodium peroxide gives oxygen, and its rapidity of flow may be quite easily regulated. The generator consists of a 300 to 400 c. c. Erlenmeyer flask fitted with a stop-cock funnel (see p. 89 of this Journal) and a delivery tube. The bottom of the flask is covered to the depth of about a centimeter with the peroxide, and the water allowed to drop on it just fast enough to keep up the evolution of the gas at the desired rate. The oxygen thus obtained is fairly dry, but to insure its perfect dryness a small calcium chloride tube can be readily attached to the delivery tube. Such an apparatus takes up but little room, can be put together in a very short time and requires but little attention to secure a pretty uniform flow of oxygen. For those who can afford the rather high-priced peroxide this method of preparation of oxygen is to be recommended for students' use also.

Metallic Sodium in Blowpipe Work. A small piece of metallic sodium, not more than three or four inches in diameter, is hammered out flat on

Röntgen gives this explanation of maximum density, but attributes it to another originator.

PRESSURE RELATIONS OF WATER.

He further assumes that an increase of pressure upon a mass of water kept at constant temperature results in some of the ice molecules changing into molecules of the second kind, and that the number so changing is greater, as the total number of ice molecules present is greater. This transformation causes a diminution of volume, which is greater, for a given pressure, at low temperatures, because then water is richer in ice molecules. Hence, when pressure acts on a mass of water the resulting change of volume is made up of—

1. A diminution of volume, due to the change of ice molecules into the second kind.

2. A diminution, due to the compression of the mass of molecules of the second kind.

The first of these effects will grow smaller as the temperature rises, because, with rising temperature, the number of ice molecules becomes less. The second will probably grow larger as the temperature goes up; at least, this is how liquids usually act. From the opposition of the effects of temperature, it can be seen that there might be some temperature at which the compressibility of water is at a minimum. According to the results of S. Pagliani and G. Vicentini* there is such a temperature at 63° C.

It is also found that the coefficient of thermal expansion of water, at least through a considerable range of temperature, increases as the pressure rises. With ether, carbon bisulphide and alcohol, the opposite is true. To find the explanation of this, consider the effect of an increase of pressure upon each of the volume changes considered under the heading "The Maximum Density of Water." The first, the diminution of volume, will be rendered less important by an increase of pressure, because by pressure the number of ice molecules is diminished, so that fewer are left to be changed by heat. Röntgen had no data from which to determine how pressure would affect the second. He thought it probable that there would be but little change. In that case, with rising pressure, the contraction of volume grows less and less,

*Beiblätter, VIII., 794.

while the normal expansion of the molecules of the second kind is unchanged, and the observed expansion of water, which is the difference of the two effects, should increase, as indeed it does.

Since, then, the unusual variation of the coefficient of thermal expansion of water with pressure is ascribed to the presence of ice molecules, it would be expected that the fewer of them there are, the less the irregularity would come in evidence. Hence, water at a high temperature or under a high pressure should manifest the variation to a less degree than at low temperatures or under low pressure. Amagat found that this is true.

He also found that the temperature of maximum density of water is lowered by pressure. According to the explanation already given of the existence of such a temperature, it is due to the presence of ice molecules. Could sufficient pressure be put upon water at 0° C. to cause all the ice molecules to disappear, probably there would be an uninterrupted expansion of volume as the temperature rose to the boiling point. We have seen that at 4° C. the effect upon the volume caused by an infinitesimal increase of temperature is zero, because the two opposing volume changes just balance each other. An increase of pressure lessens the number of the ice molecules and consequently gives to the expansion of the molecules of the second kind the preponderance. Under this increased pressure the balancing of the opposite effects no longer takes place at 4° C., but at some lower temperature, where the number of ice molecules is greater.

By pressure water can be cooled below 0° C. without freezing, because pressure prevents the formation of ice molecules.

VISCOSITY OF WATER.

Water under high pressure is less viscous than at atmospheric pressure. Generally its viscosity is made greater by dissolving other substances in it, and the larger the quantity of the solute the greater the viscosity. Its viscosity would accordingly be expected to increase with the number of ice molecules present. An increase of pressure by diminishing their number likewise diminishes the viscosity. An increase of temperature also acts to lower the viscosity by reducing the proportion of ice molecules, and very likely also by reducing the viscosity of the mass of molecules of the second kind as well.

(*To be continued.*)

Recent work on *Selenium* shows that it exists in three distinct forms, the liquid (including vitreous, amorphous and soluble), the red crystalline and the gray crystalline (or metallic) form. Its specific gravity varies from 4.26 to 4.80.

Book Reviews.

A Reader in Physical Geography for Beginners. By RICHARD ELWOOD DODGE, Professor of Geography in Teachers' College, Columbia University. Longmans, Green & Co., New York. 13x19 cms., ix and 237 pages. $0.70.

This book is designed to be used in connection with a text-book and is for information rather than study; for suggestion rather than for daily class work. It is written in an interesting manner, smooth in style, by one thoroughly competent to deal with the subject. The book discusses the following topics: The continents, the industries of men, the origin of land forms, the great land forms, climate, and other physical features. To each of these topics several chapters are devoted; for example, under great land forms are described plains and plateaus, mountains, volcanoes and movements of the land.

The pictures are well selected, many of them being from photographs taken by the author, and each is accompanied by a short explanatory statement directing the reader's attention to what is most important in the picture. The maps also are explained in the same way. The parts devoted to the origin of land forms, and to great land forms, are particularly interesting and satisfactory. The references to local geographic features are frequent, and the explanation of drowned valleys, and how in the case of the Hudson, as explained on page 169, we prove that it is drowned, is very clear and instructive.

Prof. Dodge has produced a valuable and instructive book, which ought to be widely used as a supplementary reading book in older classes.

R. H. C.

Elements of Descriptive Astronomy. By HERBERT A. HOWE, A. M., Sc. D., Professor of Astronomy in the University of Denver. 14x21 cms., 340 pages. Silver, Burdette & Co., Boston. 1900. $1.40.

This book, intended to follow algebra and geometry in the secondary school, furnishes ample material for a year's work and affords some opportunity for intelligent selection by the teacher. As a rule the topics attempted are treated fully enough for the comprehension of the average

high school pupil, and in this respect this book is better suited to its purpose than most condensed editions of college text-books.

Observational methods of study are early introduced and are continued throughout the book to a reasonable degree. In the opening chapters the pupil is led through easy and interesting descriptive matter to the more difficult subject of celestial measurements.

Ingenious illustrations of celestial motions by similar effects within the experience of the pupil stamp the author as a resourceful teacher. Much encouragement in the use of models and drawings lends definiteness to the observational work, while numerous lists of suggestive questions stimulate the imagination in its application to infinite lines and surfaces.

Pertinent historical and literary allusions throughout the book, with numerous portraits of the pioneers in astronomical research, and a chapter on "Landmarks in the History of Astronomy," are unique features. A very detailed chapter on the constellations as a guide to their telescopic study, a fully annotated list of useful reference books and an attractive list of topics for essays are particularly suggestive to the teacher.

Numerous and excellent illustrations, some of which are colored, good print and paper and handsome binding give the book a mechanical excellence of the first order.

There can be no doubt that this attractive, readable astronomy will be welcomed by many students and teachers, either as a popular reference book or as a reliable high-school text-book.

Lake View High School, Chicago.....W. S. Davis

A Text-book of Astronomy. By George C. Comstock, Director of the Washburn Observatory and Professor of Astronomy in the University of Wisconsin. 13x19 cms, viii and 391 pages. D. Appleton & Co., New York. 1901. $1.50.

While writers of current texts in elementary astronomy usually manifest a disposition to keep three or four classes of readers within their audiences, Professor Comstock apparently deems it wiser to "keep an eye single" to the needs of the student of astronomy. The emphasis of his thought is everywhere and obviously upon the *educative* value of the study, so that practical exercises and experiments with simple, inexpensive apparatus have found a prominent place throughout the book.

A large number of the illustrations are novel, ingenious and quite as worthy of close study as is the text. The writer has always found that some such simple devices as the one on page 7 for taking the sun's altitude, or the plumb-line apparatus described on page 13, together with such exercises as are given in connection with these and similar devices, will go farther to stimulate a boy's appreciative interest in astronomy and to awaken the true scientific spirit within him than will volumes of loose, popular and imaginative writing about the wonders of the heavens.

Another novel and distinctly commendable feature is the explanation

of the use of the eclipse map on page 112. No other astronomical subject attracts more interest among the laity than do eclipses. Whether this is because the frequent verifications of astronomical prediction afforded by eclipses arouses a greater respectability of credence in the popular mind than do the more occasional celestial phenomena, or because of the awe with which observed eclipses strike the unscientific mind, or for both or neither of these reasons, it would be difficult to say. It is certain, however, that there is a wholesome and widespread desire on the part of semi-scientific persons to learn how to use the data relating to eclipses of the American Ephemeris, *to which astronomers can afford to pander.* Moreover, it would seem more in accord with the purpose of a text-book for beginners to teach the methods of *using* eclipse data, than to expatiate upon the glories of an eclipse, or to present a fragmentary outline of the mathematical theory of eclipses, as is the wont of so many writers of elementary texts.

The rare instinct of the teacher is most conspicuously displayed in the rather copious use made of mathematical formulas. The idea seems to be to give the student a clear grasp of the underlying principles of both practice and theory, so far as unavoidable limitations will permit, without a desire either to eliminate or to lug in the mathematics of the subject. The idea that mathematical methods are intrinsically unlovely, or forbidding, to the student, we are glad to note, does not seem to have infected the author. When a principle can be more vigorously and readily seized by the aid of a formula, advantage is taken of it; but when the more direct route seems to lie through an experiment, or a sketch of the strategic outlines of an argument, the mathematics is omitted.

The employment of many cuts from photographs which contain the evidence for prevailing views, together with directions to the student as to the using of these cuts to verify the views for himself, will fan his latent scientific instincts and lead him to feel that astronomy is not a science of truth by authority of dogma; but that it is founded upon observation, classification and generalization quite as completely as are physics, botany, zoölogy and chemistry.

The writer would, however, criticise the statement beginning at the bottom of page 234 as misleading: "Instead of moving in orbits which are approximately parallel to the plane of the ecliptic, as do the satellites of the other planets, their (the satellites of Uranus') orbit planes are tipped up, etc., etc." The orbit planes of the satellites of Saturn can scarcely be regarded as "approximately parallel" to the plane of the ecliptic. No doubt this was an oversight and will be rectified in later editions of this book, which is certainly destined to run through several editions.

On the whole there is so much to commend in this book and so little to condemn either in purpose or execution, that the plainest statements of fact about it sound like fulsome praise. It is a presentation of the elements of the science along correct modern lines in such way as to be

admirably adapted to both the secondary schools and to the earlier years of the colleges and universities.

The publishers have added not a little to the value of the book in the way of excellent typography and artistic reproduction. Both in spirit and in form it is deserving of the appellation of a Twentieth Century Text-book.

G W. M.

Studies of Plant Life. A Series of Exercises for the Study of Plants. By HERMAN S. PEPOON, WALTER R. MITCHELL, FRED B. MAXWELL, Instructors in Biology in the Chicago High Schools. 13x18 cms., vi and 95 pages. D. C. Heath & Co., Boston. 1900. $0.50.

This little book contains two parts and an appendix. One would naturally expect Part I. to be made up of spore-plants and Part II. of seed-plants. Instead, Part I. deals with vegetative stages, reproductive stages, and life problems of types of all plants, divided into four groups: Thallophytes, 10 types; Bryophytes, 2 types; Pteridophytes, 3 typeh; Spermatophytes, 2 types—17 studies in all.

Part II. is more heterogeneous, being made up mostly of a more detailed study of seed-plants—a sort of organography. Renaming the studies of Spermatophytes as Group 5 must be an oversight.

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L. M.

The Institute adopted this view and by the law of March 30, 1791, sanctioned the selection "of a unit that had no relation to any particular

LOI

Relative au moyen d'établir une uniformité de Poids & Mesures

Donnée à Paris, le 30 Mars 1791

LOUIS, par la grâce de Dieu, & par la Loi constitutionnelle de l'État, ROI DES FRANÇOIS · A tous presens & à venir; SALUT.

L'ASSEMBLÉE NATIONALE a décrété, & Nous voulons & ordonnons ce qui suit:

DÉCRET DE L'ASSEMBLÉE NATIONALE, du 26 Mars 1791.

Title of the law establishing the Metric System. From a poster of the time.

people or place on the entire globe." The base of this system was to be the length of one-quarter of a terrestrial meridian, and the measurements necessary to determine this base by measuring an arc of the meridian between Dunkirk and Barcelona were ordered to be made.

The Academy immediately named the members of the different committees who were to execute various portions of the work, especially to fix the unit of length and the unit of weight. The principal task was given to Delambre and Méchain and in the summer of 1792 they began operations. We need not recount the technical and political difficulties they conquered. Suffice it to say they gave the value of 5,130.738.62 toises to the arc, and before they finished their work it was decided that one ten-millionth of this fundamental unit should be the practical unit of

laboratory and field method as the best. Evolution of these books shows a slow transition from the systematic through the morphological to the physiological standpoint, at present laying great stress on ecology.

"Again, of the two phases of plant life, which is the more important? Summing up, then, we have for consideration:

"1. The importance of teaching botany by the laboratory and field method.

"2. Text-books.

"3. Relative importance of the study of germinations, seedlings; the adult plant—flowers, fruit and seeds.

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The chairman suggested that some plant identification might form a part of high-school work. Another speaker rose, asking the amount of plant analysis advisable. Mr. Murbach answered that the Detroit Central High-School took from three to ten plants.

In answer to a question about new text-books, the chair suggested Coulter's Plant Studies, Barnes' Outline of Plant Life, Bergen's Foundations, Atkinson's Elements, Bailey's Elementary Botany, and, for teachers, Ganong's Teaching Botanist. The question was asked, "How much time is taken for botany in Detroit?" The answer was, "Ten months, five recitations per week, two periods long."

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following upon the study of the flower, perhaps as much time might be given as to the study of the gross anatomy of the seed, made earlier in the course. Attention should be given chiefly to the origin of the various parts of the fruit, and to the adaptation for dissemination." The chair pointed out that much teaching of ecology has been done all along, but it has not received that formal title.

Topic 4 was not discussed, the speaker to whom it was intrusted not being present. Mr. Randall was called upon to discuss the subject, "Should universities give credit for high-school botany?" Mr. Randall being ill, it devolved upon the chair. It was said that the University of Michigan had given credit for valuable work done beyond the required work. The question arose, "What is the use of studying botany in the high-school if the student is to repeat the work in college?" One speaker said that credit is sometimes given for high-school botany at Cornell.

The chair then raised a point as to the study of flowerless plants, "Where should they be introduced in the course?" One speaker offered as a phase of this subject for discussion, "Is it possible for high-school pupils to be shown the development of sexual reproduction, through the asexual?" Experience was offered on this line by Miss Williamson; a valuable result of such teaching is, that pupils see the unity in nature. She had followed the suggestions of Prof. Bessey. Dr. Pollock asked Miss Williamson, "How much had the compound microscope been used?" Her answer was, "Some, with algae."

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In closing, Mr. Murbach called attention to the fact that the experiments in the biological exhibit were entirely set up by Detroit students, and that one of the chief things shown is, how much can be done by second year high-school students in improvising apparatus for plant physiology.

Reported by L. MURBACH.

SCIENCE TEACHERS OF WISCONSIN NORMAL SCHOOLS.

On the 14th of June the science teachers of the seven Normal Schools of Wisconsin assembled at Madison in response to a call from State Superintendent Harvey to prepare more uniform courses of study in science than had hitherto existed in the schools.

The session continued for three days, and submitted courses in Physics, Chemistry, Zoölogy, Botany, Geology, Physiography, Geography, Physiology and Agriculture.

Noticeable in Supt. Harvey's address of instruction to the session was his disclaimer of any attempt to regulate the *order* in which the topics of any one science were to be taught, the *method* of instruction, or the *length of time* given to any topic. Consideration by the session was confined to the *topics* of each science, the relative amount of time given to class work and laboratory, suggested lists of experiments and necessary apparatus and a distinction between advanced and elementary *work as regards the Normal Schools.*

This is the first of a series of conferences instituted by Supt. Harvey, beginning with a general institute of all the Normal School faculties held at Oshkosh, Wis., the first of the year, and now to be continued in each department of instruction. If the first meeting of the science teachers is a prophecy of those to come, the plan will be of the greatest value, as it has facilitated, to a great degree, the understanding among the science teachers of the various schools of their duties and relations, and the very considerable fear of an attempt to hamper the individuality of the teachers by a rigid syllabus of work has been shown to be groundless.

Reported by E. C. CASE.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirtieth meeting of the Association was held in Holyoke, Mass., Saturday, May 25. The members of the Association were the guests of Mr. J. T. Draper, of the Holyoke High School. The meeting was called to order by President Herbert J. Chase, and after the transaction of routine business the report of the standing committee on apparatus was read. The committee, through its chairman, Mr. C. H. Andrews, called attention to (1) a motor-rotator so made that the rotations may be either about a horizontal or vertical apis, a speed indicator indicating the actual number of revolutions; (2) an "all-aluminum balance," mounted on a glass base, enclosed in a glass case, having an eight-inch beam and sensitive to one milligram under a load of one hundred grams. The price of the rotator is $20.00 and of the balance is $15.00.

Copies of the Manual for 1901 were distributed. Mr. J. C. Packard reported progress in his effort to secure co-operation of similar associations in England.

The address of the meeting was given by Prof. Arthur L. Kimball, Ph. D., of Amherst College, on "Electro-Magnetic Waves and their Relation to Light." After discussing the development of the electro-magnetic theory of light up to the time of Maxwell, he said: "Maxwell was led to the conclusion that electric and electro-magnetic phenomena might be explained by the supposition of an electric medium capable of certain in-

ternal motions and possessing certain mechanical properties, and to avoid the unscientific process of thought of postulating two different ethers he was led to suppose that the medium on which electric effects and optical phenomena depend for their existence is one and the same." The speaker recalled the fact that the velocity of propagation of light and electro-magnetic phenomena have been shown by experiment to be the same. He then described the experiments by which Hertz established this generalization, and pointed out resemblances between the electro-magnetic and light waves, exhibiting by means of charts the mode of starting and the advance of electro-magnetic waves in the ether. In conclusion, Prof. Kimball mentioned the following books as suggestive reading on this subject: Fleming's Alternate Current Transformer, Vol. I., Chapter V., and Watson's Text-Book of Physics, Chapters XIX. and XX.

After lunch the members visited the Holyoke dam and headgate house, and were then taken to the flume, and there, through the courtesy of Engineer A. F. Sickman, shown the method of testing the practical and theoretical efficiency of the turbines, a wheel having been placed in position purposely for this demonstration.

Reported by LYMAN C. NEWELL.

Correspondence.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

DISCUSSION OF QUESTIONS.

22. *To what extent should a pupil doing laboratory work be thrown upon his own resources in the overcoming of any difficulties that may arise?*

The manipulation of apparatus is in a certain sense an art, and like other arts has usually to be learned through imitation and by practice. Any difficulties of manipulation should be foreseen by the instructor and the student taught how to surmount them. It is indeed true that an occasional failure in manipulation teaches much and that the pupil who is shown just how to do an experiment will not gain much power of originality in performing it. But it must be borne in mind that in the laboratory good habits must be learned. For one good way of carrying out a certain manipulation there are several poor ones, and the student is more than liable to find out for himself the poor ones. With constant attention and correction on the part of the teacher, however, the pupil will sooner or later acquire habits of manipulation that will make him less and less liable

to do things in a wrong way. He can then be thrown more and more upon his own resources, although he should always be made to feel that his manner of working is being closely supervised. C. E. L.

23. *Why is it that the students of the physical sciences do not usually know how to do the simplest algebraic work, even though they have had courses in algebra and geometry?*

24. *How can the poor mathematical work done by students of the physical sciences be improved?*

These questions came up incidentally in the Chemistry Round Table Conference of the National Educational Association at its meeting in Detroit, July 11, 1901. Abstracts of what was said at that time here follow:

Mr. E. H. Heacock, Topeka, Kas.—"My pupils are frightened by a proportion or a fraction in their study of chemistry. The fault does not seem to lie with the teachers of mathematics because the pupils *do* know their algebra and geometry. I do not know where the trouble lies."

Mr. Newman, Cincinnati.—"It can't be a case of having forgotten their mathematics, for pupils in my classes have been studying advanced algebra and geometry at the same time with their physics and chemistry; they certainly know enough of mathematics, but they don't seem to know how to apply it."

Mr. Courtois, Detroit.—"I find the following remedy effective. I give my classes a lesson on the mathematical questions involved."

Mr. B. W. Peet, Ypsilanti.—"The difficulty does not arise from the student's lack of knowledge of his mathematics. I require my students to make up standard solutions of alkalis, then, by titration, with known acids, to determine whether the alkali solution is exact. These same people are students in calculus and geometry, but the above mentioned problem always causes difficulty."

Mr. Frederick C. Adams, Providence, R. I.—"I should like to offer as a suggestion an expedient that has proved useful to me. My students substitute x, y, or z for the unknown quantity. This gives them familiar mathematical expressions. Now, further, it appears to me that in science, teachers have one of the rarest opportunities in the whole field of education. It is to bring into correlation the two subjects of science and mathematics."

Mr. C. W. Parsons, Evanston, Ill.—"I would go back to the mathematical texts and ask for better problems there; i. e., examples in science."

Mr. C. E. Linebarger, Chicago.—"The trouble with that would be that we would have to get a new set of mathematics teachers. The majority of those now teaching mathematics have neither sympathy nor knowledge of science. It would certainly be a most excellent thing, however, if it were possible to substitute some physical and chemical problems for the usual "John and James" and "apples and pears" ones to be found in our algebras. This is a matter that demands attention, and a campaign of education should be started."

Recent work on *Selenium* shows that it exists in three distinct forms, the liquid (including vitreous, amorphous and soluble), the red crystalline and the gray crystalline (or metallic) form. Its specific gravity varies from 4.26 to 4.80.

Book Reviews.

A Reader in Physical Geography for Beginners. By RICHARD ELWOOD DODGE, Professor of Geography in Teachers' College, Columbia University. Longmans, Green & Co., New York. 13x19 ems., ix and 237 pages. $0.70.

This book is designed to be used in connection with a text-book and is for information rather than study; for suggestion rather than for daily class work. It is written in an interesting manner, smooth in style, by one thoroughly competent to deal with the subject. The book discusses the following topics: The continents, the industries of men, the origin of land forms, the great land forms, climate, and other physical features. To each of these topics several chapters are devoted; for example, under great land forms are described plains and plateaus, mountains, volcanoes and movements of the land.

The pictures are well selected, many of them being from photographs taken by the author, and each is accompanied by a short explanatory statement directing the reader's attention to what is most important in the picture. The maps also are explained in the same way. The parts devoted to the origin of land forms, and to great land forms, are particularly interesting and satisfactory. The references to local geographic features are frequent, and the explanation of drowned valleys, and how in the case of the Hudson, as explained on page 169, we prove that it is drowned, is very clear and instructive.

Prof. Dodge has produced a valuable and instructive book, which ought to be widely used as a supplementary reading book in older classes.

R. H. C.

Elements of Descriptive Astronomy. By HERBERT A. HOWE, A. M., Sc. D., Professor of Astronomy in the University of Denver. 14x21 cms., 340 pages. Silver, Burdette & Co., Boston. 1900. $1.40.

This book, intended to follow algebra and geometry in the secondary school, furnishes ample material for a year's work and affords some opportunity for intelligent selection by the teacher. As a rule the topics attempted are treated fully enough for the comprehension of the average

high school pupil, and in this respect this book is better suited to its purpose than most condensed editions of college text-books.

Observational methods of study are early introduced and are continued throughout the book to a reasonable degree. In the opening chapters the pupil is led through easy and interesting descriptive matter to the more difficult subject of celestial measurements.

Ingenious illustrations of celestial motions by similar effects within the experience of the pupil stamp the author as a resourceful teacher. Much encouragement in the use of models and drawings lends definiteness to the observational work, while numerous lists of suggestive questions stimulate the imagination in its application to infinite lines and surfaces.

Pertinent historical and literary allusions throughout the book, with numerous portraits of the pioneers in astronomical research, and a chapter on "Landmarks in the History of Astronomy," are unique features. A very detailed chapter on the constellations as a guide to their telescopic study, a fully annotated list of useful reference books and an attractive list of topics for essays are particularly suggestive to the teacher.

Numerous and excellent illustrations, some of which are colored, good print and paper and handsome binding give the book a mechanical excellence of the first order.

There can be no doubt that this attractive, readable astronomy will be welcomed by many students and teachers, either as a popular reference book or as a reliable high-school text-book.

Lake View High School, Chicago.....W. S. Davis

A Text-book of Astronomy. By George C. Comstock, Director of the Washburn Observatory and Professor of Astronomy in the University of Wisconsin. 13x19 cms, viii and 391 pages. D. Appleton & Co., New York. 1901. $1.50.

While writers of current texts in elementary astronomy usually manifest a disposition to keep three or four classes of readers within their audiences, Professor Comstock apparently deems it wiser to "keep an eye single" to the needs of the student of astronomy. The emphasis of his thought is everywhere and obviously upon the *educative* value of the study, so that practical exercises and experiments with simple, inexpensive apparatus have found a prominent place throughout the book.

A large number of the illustrations are novel, ingenious and quite as worthy of close study as is the text. The writer has always found that some such simple devices as the one on page 7 for taking the sun's altitude, or the plumb-line apparatus described on page 13, together with such exercises as are given in connection with these and similar devices, will go farther to stimulate a boy's appreciative interest in astronomy and to awaken the true scientific spirit within him than will volumes of loose, popular and imaginative writing about the wonders of the heavens.

Another novel and distinctly commendable feature is the explanation

of the use of the eclipse map on page 112. No other astronomical subject attracts more interest among the laity than do eclipses. Whether this is because the frequent verifications of astronomical prediction afforded by eclipses arouses a greater respectability of credence in the popular mind than do the more occasional celestial phenomena, or because of the awe with which observed eclipses strike the unscientific mind, or for both or neither of these reasons, it would be difficult to say. It is certain, however, that there is a wholesome and widespread desire on the part of semi-scientific persons to learn how to use the data relating to eclipses of the American Ephemeris, *to which astronomers can afford to pander.* Moreover, it would seem more in accord with the purpose of a text-book for beginners to teach the methods of *using* eclipse data, than to expatiate upon the glories of an eclipse, or to present a fragmentary outline of the mathematical theory of eclipses, as is the wont of so many writers of elementary texts.

The rare instinct of the teacher is most conspicuously displayed in the rather copious use made of mathematical formulas. The idea seems to be to give the student a clear grasp of the underlying principles of both practice and theory, so far as unavoidable limitations will permit, without a desire either to eliminate or to lug in the mathematics of the subject. The idea that mathematical methods are intrinsically unlovely, or forbidding, to the student, we are glad to note, does not seem to have infected the author. When a principle can be more vigorously and readily seized by the aid of a formula, advantage is taken of it; but when the more direct route seems to lie through an experiment, or a sketch of the strategic outlines of an argument, the mathematics is omitted.

The employment of many cuts from photographs which contain the evidence for prevailing views, together with directions to the student as to the using of these cuts to verify the views for himself, will fan his latent scientific instincts and lead him to feel that astronomy is not a science of truth by authority of dogma; but that it is founded upon observation, classification and generalization quite as completely as are physics, botany, zoölogy and chemistry.

The writer would, however, criticise the statement beginning at the bottom of page 234 as misleading: "Instead of moving in orbits which are approximately parallel to the plane of the ecliptic, as do the satellites of the other planets, their (the satellites of Uranus') orbit planes are tipped up, etc., etc." The orbit planes of the satellites of Saturn can scarcely be regarded as "approximately parallel" to the plane of the ecliptic. No doubt this was an oversight and will be rectified in later editions of this book, which is certainly destined to run through several editions.

On the whole there is so much to commend in this book and so little to condemn either in purpose or execution, that the plainest statements of fact about it sound like fulsome praise. It is a presentation of the elements of the science along correct modern lines in such way as to be

admirably adapted to both the secondary schools and to the earlier years of the colleges and universities.

The publishers have added not a little to the value of the book in the way of excellent typography and artistic reproduction. Both in spirit and in form it is deserving of the appellation of a Twentieth Century Text-book.

G W. M.

Studies of Plant Life. A Series of Exercises for the Study of Plants. By HERMAN S. PEPOON, WALTER R. MITCHELL, FRED B. MAXWELL, Instructors in Biology in the Chicago High Schools. 13x18 cms., vi and 95 pages. D. C. Heath & Co., Boston. 1900. $0.50.

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L. M.

Books Received.

Chemical Lecture Experiments. By Francis Gano Benedict. The Macmillan Co., New York, 1901. xiii and 436 pages. $2.00.

Induction Coils, How to Make, Use, and Repair Them. By H. S. Norrie (Norman H. Schneider). Second Edition, Revised and much enlarged. Spon & Chamberlain, New York, 1901. xvi and 269 pages. $1.00.

A Hand-book for Teachers of Chemistry in Secondary Schools. By J. A. Giffin, B. A., LL. B., Collegigate Institute, St. Catherine's Ont. William Briggs, Toronto, 1901. vi and 75 pages. 60 cents.

Free-hand Perspective. By Victor T. Wilson. John Wiley & Sons, New York, 1900. xii and 257 pages. $2.00.

An Elementary Treatise on Qualitative Chemical Analysis. By J. F. Sellers. Ginn & Co., Boston, 1900. iv and 160 pages. 75 cents.

A Text-book of Commercial Geography. By Cyrus C. Adams. D. Appleton & Co., New York, 1901. xv and 505 pages. $1.30.

CLEARING HOUSE.

Teachers desiring to offer for exchange books, apparatus, etc., may insert a notice to that effect at the nominal rate of one cent per word, *in advance*.

WANTED—A complete set of the genuine Bock-Steger Anatomical Models; second-hand models in good condition will answer. Write at once to H. R. Hamilton, Oak Park, Ill., stating lowest cash price, delivered Chicago.

Reports of Meetings.

N. E. A. ROUND TABLE CONFERENCE IN BOTANY.

WEDNESDAY, JULY 10, 4:30 P. M.

L. Murbach, Detroit, *Chairman; Helen King*, E. Saginaw, Mich., *Secretary*.

The chairman opened the meeting by a short outline of the aims of the conference and suggestion of topics for discussion. He said, in part:

"The three factors in considering any school study are the boy, the teacher, and the subject. Of most practical value to those gathered here will be the subject. What kind of botany teaching will bring best results, whether for culture, for introduction to science, practical knowledge of plants, or the requirements of teaching? Many elementary text-books have been written, treating plants from different standpoints and in about as many different fashions as there are authors, though all agree on the

laboratory and field method as the best. Evolution of these books shows a slow transition from the systematic through the morphological to the physiological standpoint, at present laying great stress on ecology.

"Again, of the two phases of plant life, which is the more important? Summing up, then, we have for consideration:

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Reported by L. Murbach.

SCIENCE TEACHERS OF WISCONSIN NORMAL SCHOOLS.

On the 14th of June the science teachers of the seven Normal Schools of Wisconsin assembled at Madison in response to a call from State Superintendent Harvey to prepare more uniform courses of study in science than had hitherto existed in the schools.

The session continued for three days, and submitted courses in Physics, Chemistry, Zoölogy, Botany, Geology, Physiography, Geography, Physiology and Agriculture.

Noticeable in Supt. Harvey's address of instruction to the session was his disclaimer of any attempt to regulate the *order* in which the topics of any one science were to be taught, the *method* of instruction, or the *length of time* given to any topic. Consideration by the session was confined to the *topics* of each science, the relative amount of time given to class work and laboratory, suggested lists of experiments and necessary apparatus and a distinction between advanced and elementary *work as regards the Normal Schools.*

This is the first of a series of conferences instituted by Supt. Harvey, beginning with a general institute of all the Normal School faculties held at Oshkosh, Wis., the first of the year, and now to be continued in each department of instruction. If the first meeting of the science teachers is a prophecy of those to come, the plan will be of the greatest value, as it has facilitated, to a great degree, the understanding among the science teachers of the various schools of their duties and relations, and the very considerable fear of an attempt to hamper the individuality of the teachers by a rigid syllabus of work has been shown to be groundless.

Reported by E. C. CASE.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirtieth meeting of the Association was held in Holyoke, Mass., Saturday, May 25. The members of the Association were the guests of Mr. J. T. Draper, of the Holyoke High School. The meeting was called to order by President Herbert J. Chase, and after the transaction of routine business the report of the standing committee on apparatus was read. The committee, through its chairman, Mr. C. H. Andrews, called attention to (1) a motor-rotator so made that the rotations may be either about a horizontal or vertical apis, a speed indicator indicating the actual number of revolutions; (2) an "all-aluminum balance," mounted on a glass base, enclosed in a glass case, having an eight-inch beam and sensitive to one milligram under a load of one hundred grams. The price of the rotator is $20.00 and of the balance is $15.00.

Copies of the Manual for 1901 were distributed. Mr. J. C. Packard reported progress in his effort to secure co-operation of similar associations in England.

The address of the meeting was given by Prof. Arthur L. Kimball, Ph. D., of Amherst College, on "Electro-Magnetic Waves and their Relation to Light." After discussing the development of the electro-magnetic theory of light up to the time of Maxwell, he said: "Maxwell was led to the conclusion that electric and electro-magnetic phenomena might be explained by the supposition of an electric medium capable of certain in-

ternal motions and possessing certain mechanical properties, and to avoid the unscientific process of thought of postulating two different ethers he was led to suppose that the medium on which electric effects and optical phenomena depend for their existence is one and the same." The speaker recalled the fact that the velocity of propagation of light and electro-magnetic phenomena have been shown by experiment to be the same. He then described the experiments by which Hertz established this generalization, and pointed out resemblances between the electro-magnetic and light waves, exhibiting by means of charts the mode of starting and the advance of electro-magnetic waves in the ether. In conclusion, Prof. Kimball mentioned the following books as suggestive reading on this subject: Fleming's Alternate Current Transformer, Vol. I., Chapter V., and Watson's Text-Book of Physics, Chapters XIX. and XX.

After lunch the members visited the Holyoke dam and headgate house, and were then taken to the flume, and there, through the courtesy of Engineer A. F. Sickman, shown the method of testing the practical and theoretical efficiency of the turbines, a wheel having been placed in position purposely for this demonstration.

Reported by LYMAN C. NEWELL.

Correspondence.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

DISCUSSION OF QUESTIONS.

22. *To what extent should a pupil doing laboratory work be thrown upon his own resources in the overcoming of any difficulties that may arise?*

The manipulation of apparatus is in a certain sense an art, and like other arts has usually to be learned through imitation and by practice. Any difficulties of manipulation should be foreseen by the instructor and the student taught how to surmount them. It is indeed true that an occasional failure in manipulation teaches much and that the pupil who is shown just how to do an experiment will not gain much power of originality in performing it. But it must be borne in mind that in the laboratory good habits must be learned. For one good way of carrying out a certain manipulation there are several poor ones, and the student is more than liable to find out for himself the poor ones. With constant attention and correction on the part of the teacher, however, the pupil will sooner or later acquire habits of manipulation that will make him less and less liable

to do things in a wrong way. He can then be thrown more and more upon his own resources, although he should always be made to feel that his manner of working is being closely supervised. C. E. L.

23. *Why is it that the students of the physical sciences do not usually know how to do the simplest algebraic work, even though they have had courses in algebra and geometry?*

24. *How can the poor mathematical work done by students of the physical sciences be improved?*

These questions came up incidentally in the Chemistry Round Table Conference of the National Educational Association at its meeting in Detroit, July 11, 1901. Abstracts of what was said at that time here follow:

Mr. E. H. Heacock, Topeka, Kas.—"My pupils are frightened by a proportion or a fraction in their study of chemistry. The fault does not seem to lie with the teachers of mathematics because the pupils *do* know their algebra and geometry. I do not know where the trouble lies."

Mr. Newman, Cincinnati.—"It can't be a case of having forgotten their mathematics, for pupils in my classes have been studying advanced algebra and geometry at the same time with their physics and chemistry; they certainly know enough of mathematics, but they don't seem to know how to apply it."

Mr. Courtois, Detroit.—"I find the following remedy effective. I give my classes a lesson on the mathematical questions involved."

Mr. B. W. Peet, Ypsilanti.—"The difficulty does not arise from the student's lack of knowledge of his mathematics. I require my students to make up standard solutions of alkalis, then, by titration, with known acids, to determine whether the alkali solution is exact. These same people are students in calculus and geometry, but the above mentioned problem always causes difficulty."

Mr. Frederick C. Adams, Providence, R. I.—"I should like to offer as a suggestion an expedient that has proved useful to me. My students substitute x, y, or z for the unknown quantity. This gives them familiar mathematical expressions. Now, further, it appears to me that in science, teachers have one of the rarest opportunities in the whole field of education. It is to bring into correlation the two subjects of science and mathematics."

Mr. C. W. Parsons, Evanston, Ill.—"I would go back to the mathematical texts and ask for better problems there; i. e., examples in science."

Mr. C. E. Linebarger, Chicago.—"The trouble with that would be that we would have to get a new set of mathematics teachers. The majority of those now teaching mathematics have neither sympathy nor knowledge of science. It would certainly be a most excellent thing, however, if it were possible to substitute some physical and chemical problems for the usual "John and James" and "apples and pears" ones to be found in our algebras. This is a matter that demands attention, and a campaign of education should be started."

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THE CONSTRUCTION OF A MODEL OF NATURE.

AND

THE LIMITS OF PHYSICAL THEORIES.*

BY ARTHUR W. RÜCKER.

A natural philosopher, to use the old phrase, even if only possessed of a most superficial knowledge, would attempt to bring some order into the results of his observation of nature by grouping together statements with regard to phenomena which are obviously related. The aim of modern science goes far beyond this. It not only shows that many phenomena are related which at first sight have little or nothing in common, but, in so doing, also attempts to explain the relationship.

Without spending time on a discussion of the meaning of the word "explanation," it is sufficient to say that our efforts to establish relationships between phenomena often take the form of attempting to prove that, if a limited number of assumptions are granted as to the constitution of matter, or as to the existence of quasi material entities, such as caloric, electricity and the ether, a wide range of observed facts falls into order as a necessary consequence of the assumptions. The question at issue is whether the hypotheses which are at the base of the scientific theories now most generally accepted are to be regarded as accurate descriptions of the constitution of the universe around us, or merely as convenient fictions.

Convenient fictions, be it observed, for even if they are fic-

*From the address of the President of the British Association for the Advancement of Science, Glasgow meeting, 1901.

tions they are not useless. From the practical point of view it is a matter of secondary importance whether our theories and assumptions are correct, if only they guide us to results which are in accord with facts. The whole fabric of scientific theory may be regarded merely as a gigantic "aid to memory"; as a means for producing apparent order out of disorder by codifying the observed facts and laws in accordance with an artificial system, and thus arranging our knowledge under a comparatively small number of heads. The simplification introduced by a scheme which, however imperfect it may be, enables us to argue from a few first principles, makes theories of practical use. By means of them we can foresee the results of combinations of causes which would otherwise elude us. We can predict future events, and can even attempt to argue back from the present to the unknown past.

But it is possible that these advantages might be attained by means of axioms, assumptions and theories based on very false ideas. A person who thought that a river was really a streak of blue paint might learn as much about its direction from a map as one who knew it as it is. It is thus conceivable that we might be able, not indeed to construct, but to imagine, something more than a mere map or diagram, something which might even be called a working model of inanimate objects, which was nevertheless very unlike the realities of nature. Of course, the agreement between the action of the model and the behavior of the things it was designed to represent would probably be imperfect, unless the one were a facsimile of the other; but it is conceivable that the correlation of natural phenomena could be imitated, with a large measure of success, by means of an imaginary machine which shared with a map or diagram the characteristic that it was in many ways unlike the things it represented, but might be compared to a model in that the behavior of the things represented could be predicted from that of the corresponding parts of the machine.

We might even go a step further. If the laws of the working of the model could be expressed by abstractions, as, for example, by mathematical formulæ, then, when the formulæ were obtained,

the model might be discarded, as probably unlike that which it was made to imitate, as a mere aid in the construction of equations, to be thrown aside when the perfect structure of mathematical symbols was erected.

If this course were adopted we should have given up the attempt to know more of the nature of the objects which surround us than can be gained by direct observation, but might nevertheless have learned how these objects would behave under given circumstances.

We should have abandoned the hope of a physical explanation of the properties of inanimate nature, but should have secured a mathematical description of her operations.

There is no doubt that this is the easiest path to follow. Criticism is avoided if we admit from the first that we can not go below the surface; can not show anything about the constitution of material bodies; but must be content with formulating a description of their behavior by means of laws of nature expressed by equations.

But if this is to be the end of the study of nature, it is evident that the construction of the model is not an essential part of the process. The model is used merely as an aid to thinking; and if the relations of phenomena can be investigated without it, so much the better. The highest form of theory—it may be said—the widest kind of generalization, is that which has given up the attempt to form clear mental pictures of the constitution of matter, which expresses the facts and the laws by language and symbols which lead to results that are true, whatever be our view as to the real nature of the objects with which we deal. From this point of view the atomic theory becomes not so much false as unnecessary; it may be regarded as an attempt to give an unnatural precision to ideas which are and must be vague.

Thus, when Rumford found that the mere friction of metals produced heat in unlimited quantity, and argued that heat was therefore a mode of motion, he formed a clear mental picture of what he believed to be occurring. But his experiments may be quoted as proving only that energy can be supplied to a body in

indefinite quantity, and when supplied by doing work against friction it appears in the form of heat.

By using this phraseology we exchange a vivid conception of moving atoms for a colorless statement as to heat energy, the real nature of which we do not attempt to define; and methods which thus evade the problem of the nature of the things which the symbols in our equations represent have been prosecuted with striking success, at all events within the range of a limited class of phenomena. A great school of chemists, building upon the thermodynamics of Willard Gibbs and the intuition of Van't Hoff, have shown with wonderful skill that, if a sufficient number of the data of experiment are assumed, it is possible, by the aid of thermodynamics, to trace the form of the relations between many physical and chemical phenomena without the help of the atomic theory.

But this method deals only with matter as our coarse senses know it; it does not pretend to penetrate beneath the surface.

It is therefore with the greatest respect for its authors, and with a full recognition of the enormous power of the weapons employed, that I venture to assert that the exposition of such a system of tactics cannot be regarded as the last word of science in the struggle for the truth.

Whether we grapple with them, or whether we shirk them; however much or however little we can accomplish without answering them, the questions still force themselves upon us: Is matter what it seems to be? Is interplanetary space full or empty? Can we argue back from the direct impressions of our senses to things which we cannot directly perceive; from the phenomena displayed by matter to the constitution of matter itself?

It is these questions which we are discussing tonight, and we may therefore, as far as the present address is concerned, put aside, once for all, methods of scientific exposition in which an attempt to form a mental picture of the constitution of matter is practically abandoned, and devote ourselves to the inquiries whether the effort to form such a picture is legitimate, and whether we have any reason to believe that the sketch which science has already drawn is to some extent a copy, and not a mere diagram, of the truth.

THE LIMITS OF PHYSICAL THEORIES.

And this brings me to my last point. It is a mistake to treat physical theories in general, and the atomic theory in particular, as though they were parts of a scheme which has failed if it leaves anything unexplained, which must be carried on indefinitely on exactly the same principles, whether the ultimate results are, or are not, repugnant to common sense.

Physical theories begin at the surface with phenomena which directly affect our senses. When they are used in the attempt to penetrate deeper into the secrets of nature it is more than probable that they will meet with insuperable barriers, but this fact does not demonstrate that the fundamental assumptions are false, and the question as to whether any particular obstacle will be forever insuperable can rarely be answered with certainty.

Those who belittle the ideas which have of late governed the advance of scientific theory too often assume that there is no alternative between the opposing assertions that atoms and the ether are mere figments of the scientific imagination, or that, on the other hand, a mechanical theory of the atoms and of the ether, which is now confessedly imperfect, would, if it could be perfected, give us a full and adequate representation of the underlying realities.

For my own part I believe that there is a *via media*.

A man peering into a darkened room, and describing what he thinks he sees, may be right as to the general outline of the objects he discerns, wrong as to their nature and their precise forms. In his description fact and fancy may be blended, and it may be difficult to say where the one ends and the other begins; but even the fancies will not be worthless if they are based on a fragment of truth, which will prevent the explorer from walking into a looking-glass or stumbling over the furniture. He who saw "men as trees walking" had at least a perception of the fundamental fact that something was in motion around him.

And so, at the beginning of the twentieth century, we are neither forced to abandon the claim to have penetrated below the surface of nature, nor have we, with all our searching, torn the veil of mystery from the world around us.

The range of our speculations is limited both in space and time: in space, for we have no right to claim, as is sometimes done, a knowledge of the "infinite universe"; in time, for the cumulative effects of actions which might pass undetected in the short span of years of which we have knowledge, may, if continued long enough, modify our most profound generalizations. If some such theory as the vortex-atom theory were true, the faintest trace of viscosity in the primordial medium would ultimately destroy matter of every kind. It is thus a duty to state what we believe we know in the most cautious terms, but it is equally a duty not to yield to mere vague doubts as to whether we can know anything.

If no other conception of matter is possible than that it consists of distinct physical units—and no other conception has been formulated which does not blur what are otherwise clear and definite outlines—if it is certain, as it is, that vibrations travel through space which cannot be propagated by matter, the two foundations of physical theory are well and truly laid. It may be granted that we have not yet framed a consistent image either of the nature of the atoms or of the ether in which they exist; but I have tried to show that in spite of the tentative nature of some of our theories, in spite of many outstanding difficulties, the atomic theory unifies so many facts, simplifies so much that is complicated, that we have a right to insist—at all events till an equally intelligible rival hypothesis is produced—that the main structure of our theory is true; that atoms are not merely helps to puzzled mathematicians, but physical realities.

THE AIMS AND PURPOSES OF MODERN WORK IN BIOLOGY.

BY FRANKLIN W. BARROWS.
Instructor in Biology, Central High School, Buffalo, N. Y.

(*Concluded from page 190.*)

The motive for this delicate and painstaking work may be described as the quest for the secret of heredity, and for those elements or objects in the egg and the sperm-cell respectively which carry the qualities of the parent down to the offspring. Omitting now all mention of early theories of heredity, let us see to what position the biologists had attained in 1878, when Huxley said: "It is conceivable and indeed probable, that every part of the adult contains molecules derived both from the male and from the female parent; and that, regarded as a mass of molecules, the entire organism may be compared to a web, of which the warp is derived from the female and the woof from the male." While the researches of the past twenty years tend to confirm this view, they have not brought us much nearer to the actual secret of development, although they have piled up an enormous mass of details and added one theory of heredity to another. The limits of this paper will not allow even the mention of the half dozen theories that have been advanced by as many leading scientists. Somewhere in the complex and intricate architecture of the living cell, undiscerned as yet by the best microscopes, eluding every test that ingenuity has devised, lurk the secrets of development and heredity and no one can declare that we are not about as far astray in our search for these secrets as were the embryologists of a century ago. But the modern biologists have really witnessed what was never seen before,—the actual division of the egg and the multiplication of germ cells and the building up of the embryo. They have learned much as to the processes involved, little as to the forces and the factors in these processes.

The last few years have seen the most novel and sensational lines of experiment in the whole history of biology,—the work in experimental embryology, much of which has been done in America. Experimenters have succeeded in separating the cells of the

growing egg and rearing complete embryos from half or a quarter of an egg,—that is to say, they have isolated the cells in the 4-cell stage of development and produced an entire embryo from one of these cells. The most striking results in experimental embryology are reported by Professor Loeb of the University of Chicago, who has succeeded in developing the eggs of sea urchins without fertilization by the spermatozoa, through the action of a solution of magnesium chloride. It is unnecessary to add that such discoveries as these produce consternation and confusion among the adherents to certain cunningly devised embryological theories. We cannot predict how soon the experimental embryologists may produce other freaks in their laboratories that shall make it necessary to revise and recast our scientific creeds. We know that the field for such experiment is great and the results are received with eager interest.

It was natural that the embryologists should engage in the most painstaking investigation of the structure and composition of the egg. And by a natural extension of this careful study to the other cells of the plant or animal there has grown up the science of *cytology,* or the study of the cell in all its stages and phases of activity. At present the chief interests of the cytologists center about two problems, viz., cell division, and the structure of protoplasm, the living substance of the cell. It seems likely that the minute study of the cell will be insisted upon in the future to supply the basis of a rational physiology. One of our leading German physiologists, Verworn, reiterates the idea that our future advance in physiology must be along the lines of cell-physiology. In most of our physiological laboratories the investigation of the living cell, and of the unicellular animals and plants is demanding increased interest.

The mere suggestion of physiology calls to our mind a long list of brilliant achievements to the credit of the past century and suggests many lines of present experiment and research. It suggests also that horrible bugbear of vivisection. There were vivisectors and experimental physiologists many years ago, but two discoveries of the last quarter century,—anaesthetics and antiseptic surgery,—have added vastly to the possible range of humane experimentation on animals, and have led to an extension

of work along these lines that has excited considerable alarm and bitter opposition on the part of a non-scientific and hyperaesthetic public. Very much beneficent work has been accomplished by the experimental physiologist,—especially in lines closely related to medicine and bacteriology,—but very much more remains to be done by future experimenters. Verworn tells us that in the future we shall see experiments in physiology bearing on the problems of descent and extending the discussions of the mechanism of heredity beyond present bounds into the domain of physiology. Another and a very different physiological problem, "the old riddle of the causal relations between body and mind," to quote the same author, "remains apparently wholly untouched by natural science." The physiologist of the future may, moreover, be able to tackle the knotty "problems of cerebral mechanics" which are today unapproachable.

So much for what we may call ultimate aims of animal physiology. There are many other objects more easily attainable by the study of living animals, a few of which are excellently expressed by Dr. Conklin, of the University of Pennsylvania.* He says:

> The usual laboratory work in zoölogy, viz., the anatomy of a few alcoholic specimens, is less than one-half of the science and in all respects the least interesting and important half. Research today is tending more and more to the study of *living* things, and in this respect, as in so many others, research points out the way for advances in teaching. The study of living animals; of their actual development under normal and experimentally altered conditions; of their food and the manner of getting it; their enemies and friends, parasites and messmates; their mating, breeding, and care of young; the effects of isolation, crossing and close breeding on structure and habits; the effects of varying light, color, temperature, density of medium, etc., on color, size and structure of every part; the daily and nightly activities of animals; the origin and nature of peculiar habits and instincts—in short, the study of all the varied ways in which animals live and adapt themselves to their environment, is an integral part of zoölogy, and who can doubt that together these things form its most important part, and yet there are few if any places where any systematic attempt is made to give instruction in these subjects.

It is encouraging to see just such work as Dr. Conklin advocates becoming more common every year, and forming a large

*Science, IX, p. 83, January 20, 1899.

part of the activity of biological stations and experimental farms, while in some of our universities, notably the University of Pennsylvania, it enters largely into the work of the student and investigator.

In speaking of physiology, we are prone to overlook that division known as plant physiology; and no wonder, for we are told that it is scarcely ten years since this subject began to receive any considerable attention in this country, although it has been cultivated in Germany and other countries for many more years. The present progress of vegetable physiology is full of promise, however. Its many bearings on the important economic aspects of agriculture and forestry are now recognized. Special problems that await investigation refer particularly to ecology, root-absorption, and chief of all, the *constitution of living matter.**

No other branch of biology is so much the creation of the last twenty years as bacteriology. Its achievements, under Pasteur, Koch, and many others, are more or less known to all intelligent people, and its popularity as a study was such that for a time all other European laboratories were well nigh forsaken by the rush of students into bacteriology. The possibilities of the science are but just beginning to be realized. It has not only saved the silk worm industries of France, but in the hands of the doctor the practical application of the teachings of bacteriology has saved hundreds of thousands of human lives. This science has found a useful field, also, in the industries of dairying, brewing, gardening, horticulture and the culture of fish and oysters. The aims and objects of bacteriology,—leagued with the science of pathology,—are nothing less than the complete revolutionizing of the conditions of human life. If such a claim appears to be a trifle extravagant, one needs only to review the progress of the past twenty-five years, and his faith in these two sciences will be abundantly renewed.

An adequate appreciation of the science of pathology ranks it under biology, although it is too often thought of as a part of the medical course. It is entirely outside the province of such a paper as this, however, to attempt to point out the numerous lines along which present investigations are advancing. It must suf-

*Science X p. 245. Sept. 8, '99. Prof. C. R. Barnes.

fice to allude to the recent interest in tropical diseases, which has led to the founding of institutes and the establishing of Commissions in this country and in England, and especially to the interesting studies during the past few years on the mosquito in its relation to diseases of man and the lower animals.

In this brief review of the biologic field it seems evident that the old line between pure science and applied science is becoming obsolete; at any rate we hear less of this distinction and we find a disposition on the part of most biologists to be of use to somebody. This disposition is fostered by our government, which employs 6,000 scientific men in its various bureaus, at an annual expense of ten million dollars. Almost every first-class college and university in the country, it is said, is doing some kind of scientific work for the United States government. Most of the states give employment to a few investigators. Taken all in all, there is an encouraging demand for practical biological work by those who are competent to carry it on. One leading biologist is studying the oyster industry of Maryland; another is propagating eastern oysters in Oregon for the U. S. Fish Commission; a college professor in New York state is studying the annelids of Porto Rico for the United States government; several men in the interior states are studying the fishes of the Great Lakes and their food supply, directed by the head professor of zoölogy at Ann Arbor. The department of botany in the State University of Nebraska is carrying on investigations for the United States government into the forest conditions of the plains. We all know something of the services rendered to the government by Dr. Jordan, the distinguished President of Stanford University, who has devoted much time to the work of the U. S. Seal Commission.

Apart from these *practical* scientists, there is still, to be sure, a lessening minority of trained biologists, who lurk in laboratories and museums and engage in what they are pleased to call researches in *pure science*. These are our biological pharisees, who treat the publicans and sinners with considerable arrogance. But most investigators realize more and more clearly that, as Dr. Hodge says, "The human values attaching to knowledge are so enormous that we have no measures or terms with which to adequately express them"; and again, that "we may not be able to

estimate the value of truth until it be discovered, and that the investigator himself, who is willing to devote his time and energies to the work, should be the one to estimate its values." Viewed in this light, all new truth becomes valuable and no one shall say what intensely practical application may follow closely upon the next biological discovery.

Never has the argument for scientific investigation been stated more clearly and forcibly than by the late Professor Rowland of Johns Hopkins University, a physicist, speaking to the Physical Society of America. He said*:

An only child, a beloved wife, lies on a bed of illness. The physician says that the disease is mortal; a minute plant called a microbe has obtained entrance into the body and is growing at the expense of its tissues, forming deadly poisons in the blood or destroying some vital organ. The physician looks on without being able to do anything. Daily he comes and notes the failing strength of his patient and daily the patient goes downward until he rests in his grave. But why has the physician allowed this? Can we doubt that there is a remedy which shall kill the microbe or neutralize its poison? Why, then, has he not used it? He is employed to cure but has failed. His bill we cheerfully pay because he has done his best and given a chance of cure. The answer is *ignorance*. The remedy is yet unknown. The physician is waiting for others to discover it, or perhaps is experimenting in a crude and unscientific manner to find it. Is not the inference correct, then, that the world has been paying the wrong class of men? Would not this ignorance have been dispelled had the proper money been used in the past to dispel it? Such deaths some people consider an act of God. What blasphemy to attribute to God that which is due to our own and our ancestors' selfishness in not founding institutions for medical research in sufficient number and with sufficient means to discover the truth! Such deaths are murder. Thus the present generation suffers for the sins of the past and we die because our ancestors dissipated their wealth in armies and navies, in the foolish pomp and circumstance of society, and neglected to provide us with a knowledge of natural laws. In this sense they were the murderers and robbers of future generations of unborn millions and have made the world a charnel house and place of mourning where peace and happiness might have been. Only their ignorance of what they were doing can be their excuse, but this excuse puts them in the class of boors and savages who act according to selfish desire and not to reason and to the calls of duty. Let the present generation take warning that this reproach be not cast on it, for it cannot plead ignorance in this respect.

This illustration from the department of medicine I have given because

*Science, X, p. 832, December 8, 1899.

it appeals to all. But all the sciences are linked together and must advance in concert. The human body is a chemical and physical problem, and these sciences must advance before we can conquer disease. * * *

Where, then, are the greatest laboratories of research in this city, in this country, nay, in the world? * * * Where in the world is the institute of pure research in any department of science with an income of $100,000,000 per year? Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But $100,000,000 per year is but the price of an army or a navy designed to kill other people. Just think of it, that one per cent. of this sum seems to most people too great to save our children and descendants from misery and even death!

If we ask now what is the spirit of the modern biology, we shall find that the workers are striving to serve mankind, to subdue the animal and vegetable kingdoms and to create more favorable conditions for human progress. Shaler and Hodge have recently shown us that out of the millions of species of plants and animals, we have as yet named and classified only the insignificant sum of 500,000. Of these we have learned to use in various ways not more than 1,000 animals and 1,000 plants. The other species are before us, presenting problems enough for centuries of study and destined sometime to become resources of enormous value. The control of these living forces is as worthy a task as the utilizing of tidal energy or the harnessing of Niagara. Just at present we are devoting our inquiries principally to the control of the bacteria and the insects.

Our sketch of the present aims of biology would be incomplete without an allusion to the intense interest manifested today in the popularizing of all biological subjects. This is evidenced by the phenomenal increase in the number of attractive books and magazine articles gotten out during the last few years for non-scientific readers. Many biologists of acknowledged authority have aided in the preparation of such books, while others, equally eminent, have gone aside from their regular work to prepare elementary text-books to take the place of older and less trustworthy authors. Even the nature study of our primary schools has engaged the earnest attention of some of our university professors, who have written articles, in a truly scientific spirit, for the children and for their teachers.

We may discern several motives for this kind of popularizing

work on the part of earnest biologists. Sometimes it is a spirit of protest against the flood of cheap shoddy which finds its way into the literary market and the schools under the guise of science, and which is much worse than no science at all. Usually, however, the authority in biology, when he addresses himself to the popular mind or to the child, does so under the profound conviction that modern society needs those lessons in altruism which can be best taught by teaching the unity of all life and of nature; or perhaps he looks on biology as of incalculable value in an economic or sociological sense, as one of the forces that is to help humanity. In any case, we pay our respects to the scholar or philosopher who brings the popular mind into closer sympathy with plants and animals. Such labors are no less fruitful than those of the investigator and discoverer.

RECENT ADVANCES IN THE PHYSICS OF WATER.

BY GEORGE FLOWERS STRADLING, PH. D.

(*Continued from page 212.*)

Röntgen predicts that "the viscosity of water at high pressures will be less reduced by a given increase of pressure than at low pressures," and also that the effect of pressure in reducing the viscosity will be greater the lower the temperature of the water. In both cases his anticipations have been confirmed experimentally by R. Cohen* and L. Hausser.†

Following the road marked out by Röntgen, a number of investigators have succeeded in finding the explanation of some of the irregularities of water which he did not discuss. Hugo Witt* of Stockholm has applied the theory to several phenomena of aqueous solutions. From the equation of equilibrium between the two kinds of water molecules in an aqueous solution he infers that the presence of the solute has the effect of causing some of

*Phil. Mag., L., 460 (1900).
†Drude's Ann., II., 1.
*Zeitschr. f. phys. Chem., XXXV., 77.

the ice molecules to change into those of the second kind. This at once explains why the volume of an aqueous solution is generally less than the sum of the volumes of the water and of the dissolved substance. The contraction is the result of the change of molecules of greater specific volume into those of less.

We have seen that an increase of pressure lowers the temperature of maximum density of water. Now both pressure and the presence of a substance in solution have the effect of reducing the number of ice molecules, and hence it appears why the temperature of maximum density of an aqueous solution is below 4° C.

Witt explains the high specific heat of water as due to the heat required to change ice molecules into those of the second kind. Solutions in water commonly have a lower specific heat than water alone. Even after making allowance for the solute, whose specific heat is less than that of water, it is found that the water in the solution seems to have a less specific heat than before the substance was dissolved in it. This is attributed to the solution having fewer ice molecules than water, so that a rise of temperature of 1° will cause the transformation of fewer of these and will therefore require a smaller addition of heat. He finds in the heat requisite to bring about the change of ice molecules into the other form a reason why the solution of substances in water is usually accompanied by a lowering of temperature.

Within the past year there has appeared a paper by Sutherland* in which the author endeavors to furnish a quantitative explanation of the behavior of water. He aims to show that steam is H_2O, ice $(H_2O)_3$ and water a mixture of H_2O and of $(H_2O)_3$. He calls H_2O *hydrol*, $(H_2O)_2$ *dihydrol*, and $(H_2O)_3$ *trihydrol*. According to this nomenclature Röntgen's ice molecules are trihydrol and his molecules of the second kind are dihydrol.

The method of determining the density of dihydrol at 0° C. is here given to serve as an example of Sutherland's manner of procedure. A curve is plotted in which the ordinates are the densities of water and the abscissas the corresponding temperatures. The curve has its maximum ordinate at 4° C., then sinks

*Phil Mag., L., 460 (1900).

toward the axis of X and appears to approach a straight line asymptotically. It seems reasonable to take this straight line as giving the density-temperature relations of one of the ingredients of ordinary water, of dihydrol, as is shown later. Following this line back until it meets the axis of Y, the density at 0° is read off as 1.083.

Mendeleeff has calculated an equation giving the density of water as a function of the temperature. The investigator throws this equation into a form in which the density is the sum of five terms. Let us now call water at 4° C., made up as is supposed of two constituents, the standard mixture. Water at any other temperature may be regarded as formed by uniting a mass of the standard mixture with a mass of dihydrol. Let the further assumption be made that both of these in expanding follow the simple law,—$\rho = \rho_0 (1 - k t)$, where

ρ_t = density at t^0
ρ_0 = density at 0^0
k = constant.

Now it is possible to calculate the density of water at any temperature upon the above suppositions and to throw the result into a form which can be compared with Mendeleeff's formula. From the comparison of the two formulas it follows that the density of dihydrol at 0° C. is 1.08942, a result agreeing well with the value 1.083 obtained graphically as explained above.

It will not escape notice how much this conclusion rests upon assumptions. The reason for believing the constituent considered to be dihydrol will be given when surface tension is discussed.

The following values are given for the fractional part by weight of trihydrol in water at different temperatures, under 1 atmosphere and 150 atmospheres respectively:

	Temp.	0°	20°	40°	60°	80°	100°	120°	140°	198°
Trihydrol at	1 atmos.	0.375	0.321	0.284	0.255	0.234	0.217	0.203	0.191	0.165
	150 atmos.	0.351	0.300	0.264	0.237	0.217	0.203	--		

It is calculated that at 2300 atmospheres the whole of the trihydrol in water is changed into dihydrol at 0° C.

(*To be continued.*)

THE PLACE OF FIELD WORK IN HIGH SCHOOL. PHYSIOGRAPHY.

BY C. W. GOODRICH.

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In speaking of the place of field work in a high-school course in physiography it is not necessary to show that it deserves a place, but the question is to determine how important it is and in what manner it can be carried out best. The matter of field work is a serious one for physiography teachers to contemplate, and is too often neglected because it means additional hours of work for the teachers. It means, however, increased interest on the part of the pupils and therefore a more rapid advance in class-room work.

The chief value of field work arises from the fact that the student comes directly into contact with the physiographic forms that he is studying about, and a form once seen is sure to be remembered much longer than one where the mental picture alone is relied upon. The latter is usually a mere hazy notion, if, indeed, any is retained at all. It is difficult to have pupils realize the extent to which the ever-acting agencies of nature are to be noted, if the opportunity to note these changes is neglected entirely. As an example, suppose one were to show a class an embankment without any vegetation upon it before and after a rain. The changes noted upon it are merely those taking place during every storm, and yet many of the typical geographical forms can be noted on it in miniature. The effect of the rain in washing out the roads might also be taken as an example of erosion of simple type.

It matters not whether the teacher is located on coast, plain or mountainous area, simple ways of illustrating the ever-acting forces of nature are always at hand, varying in kind and amount, however, with the locality. The type of field work so far mentioned, that is, explanatory and demonstrative, is just as well fitted for pupils in the lower grades as for those in the high school. This type of field work is such as may be taken up first in the study of physiography with profit, as it results in a clearer understanding on the part of the pupils. I am here supposing that

the lands are given first attention in such a course, as there is something in the study of the lands which appeals to pupils more strongly than does the ocean or the atmosphere.

Such field work as described above serves to illustrate the text-book, but it should be regarded as nature's text-book from which our text-book information is drawn. After the first of these field trips the attempt should be to draw out the pupils, that is, to lead them to make their own observations and to have them reason out the cause from the effect noted. If the pupils are without any training of this character, the progress at first will be slow, but if a little care be taken in the introductory trips the teacher will soon find that there is no end to the questions which will arise. A written report of a trip should be required, not merely as an indication of work done, but in order that the teacher may find out those pupils who have greater difficulties than some of the others. If the report is not required, there still remains a certain value from the trip, but one of the results of the report is that it fixes in the mind of the pupil that which has been explained to him and which, by writing, he has in turn shown himself capable of explaining. As soon as the pupils have gained the power of observation well, ask them questions in the field which they are to answer in their reports and encourage them to make drawings of the forms seen.

There is, however, a higher type of field work of even greater value to the pupil, that is, where a small locality is chosen and a map made of it. This work requires close attention on the part of the teacher and also much assistance from him at first. The locality should be chosen with care, as it is not the making of the map which is to be the end sought for, but it is the better and clearer understanding of how some of the smaller features of the locality have been produced. This kind of work comes best in the spring after the pupil is familiar with the general land forms and the ways in which they are produced. Even then it will be found profitable to cover the field at first in one trip with the class and then to spend more time on a closer study in which the pupils gain as much as possible for themselves, but any questions should be answered for them or they should be led to see for themselves what the answer is. In following out this plan, a preliminary or

general report should be written first, which tells what is to be studied later, and then a more definite description comprising work of later trips as well as a map and sections where they are needed. This is the plan on which the appended report is made out. It comprises the field work of two first-year pupils of the high school who worked together in one of my classes, and it may be taken as a fair sample of what can be done on trips of this nature. The work is illustrated by three photographs, the locality of which is shown on the map.

Let us look to see how much time should be spent on such work. If the field work is of the type first described, an afternoon a week should be spent in the field as long as the open weather lasts in the fall of the year. Allowance should be made to the pupil by giving him his class period for study either on the day on which he goes into the field or on the day after. In the first case it is designed as a chance to get the next day's lessons and in the second place as a means of diminishing the work of the next day.

In the second half year, devote if possible two afternoons a week to field work, preferably of the second type, at least during April and May, if the weather will allow, as the warm days of June take away the interest of such a trip, as it is then too warm for much walking, and also as the last few weeks of school require more of the teacher's time in assisting backward pupils.

The objection may be raised that the amount of time here specified can not be given by every teacher. This may be true in certain cases, but it is well to have as a motto—As much field work as possible and the more the better. It is, then, the only way to teach properly the subject of physiography, and no teacher can plead as an excuse the lack of means of illustration, as such an excuse is merely an indication of poor preparation on his part. Field work is entirely within the reach of the grade teacher as well as the high-school teacher. The work, then, should commence in the lower grades and should lead up to and prepare the way for more advanced work in the high school in just the same manner as the work of the high school should fit for the college. Let every teacher devote as much time as possible to field work, preferably that of the type mentioned for the latter half year, but

let no one do away with field work completely, as a little is better than none at all.

The following report is entirely the work of two pupils in the first year of the high school of Holyoke, Massachusetts. A few corrections in expression have been made, but the thought and the map, as well as the sections are of their own making. The photographs illustrate well the description of the parts of the brook as found in the following report:

THE WHITING STREET BROOK.

GENERAL DESCRIPTION.

The Whiting Street Brook was taken as the point of study on one of our field excursions. This brook is one of the small tributaries of the Connecticut river. Its general course is very meandering.

Near the mouth of the stream the rock is sandstone, as is also the bed. The edges of this rock are rough and uneven, with large crevices visible. This, with the slope of the land, causes numerous rapids. Owing to the hardness of the rock the stream has not been as active in cutting through it as through the glacial deposits above. Another cause of this lack of cutting is the tilt of the rock, which is here dipping the same way that the brook is flowing, that is, roughly northwest to southeast. The course of the brook has a steep slope and this, with the cause mentioned above, tends to produce a youthful or V-shaped valley. A short distance from its mouth the rock changes from sandstone to trap. The brook here does not have such jagged edges to flow over, because this kind of rock is not in layers, and can easily be rounded by the water. Another agent aiding the rounded appearance is the moss with which the rock is covered. A reason for the rapid decay of this trap rock is that the water forces its way into the joints, making the rock break in layers. The boulders in this stream produce small falls or rapids, at the base of which are pools.

In this place the valley is changing from a youthful to a more mature stage. Above here is a small temporary base-level, due to the trunk of a large tree which had fallen across its course and had also collected sediments behind it. This made the brook turn from its straight course, more to the left.

Nearer the source a small oxbow cutoff was visible. Here the rock changed back to sandstone again, the result of which caused the valley to become more mature than below. Where the bed was pebbly, the brook had cut very little, making the valley nearly level. In one place at least five courses were cut. The changing of one course was due to the root of a tree which had grown across the stream. Here also the sediments of shale and sandstone fragments were noticeable. They were deposited

upon the convex bank. Above here the rocks were tilted by the forcing upward of the lava sheet of which Mt. Tom is the remnant. The tilt is about 25 degrees to the east, making the strike north and south. The brook has flowed down the dip of the rock. A little above here a large pile of sediment was found.

As we followed along the bed of this stream, which was tilted standstone, we reached the dam of the small reservoir which has been built across the stream, thus ending the brook in its natural state.

DEFINITE DESCRIPTION.

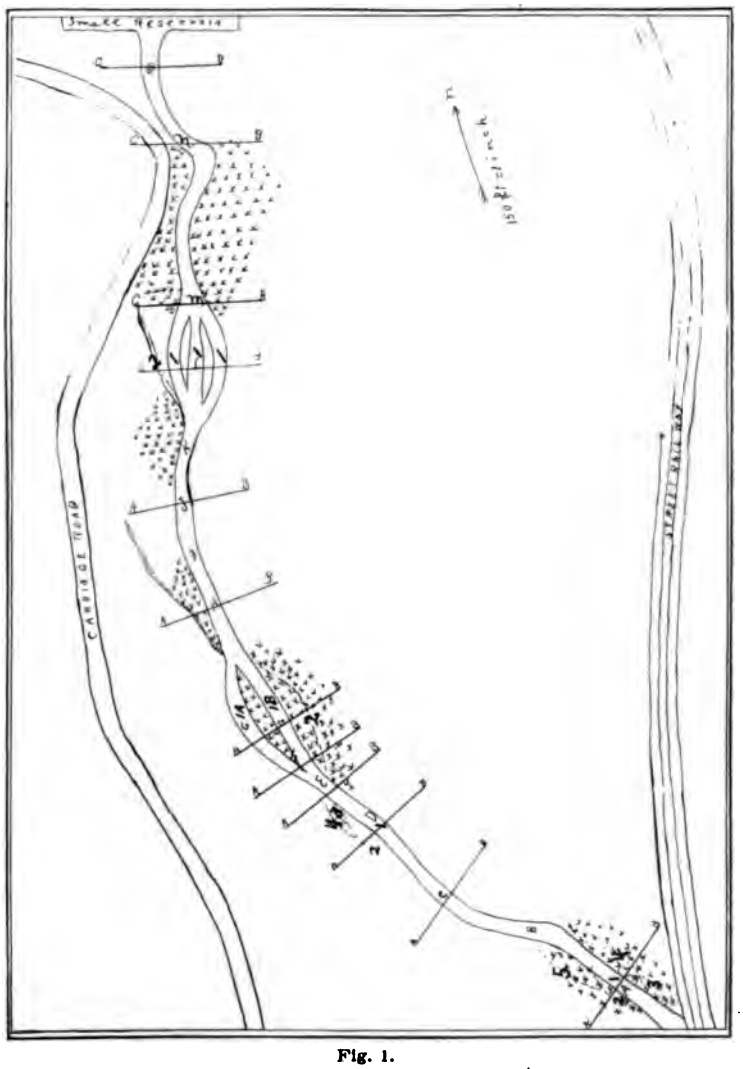

Fig. 1.

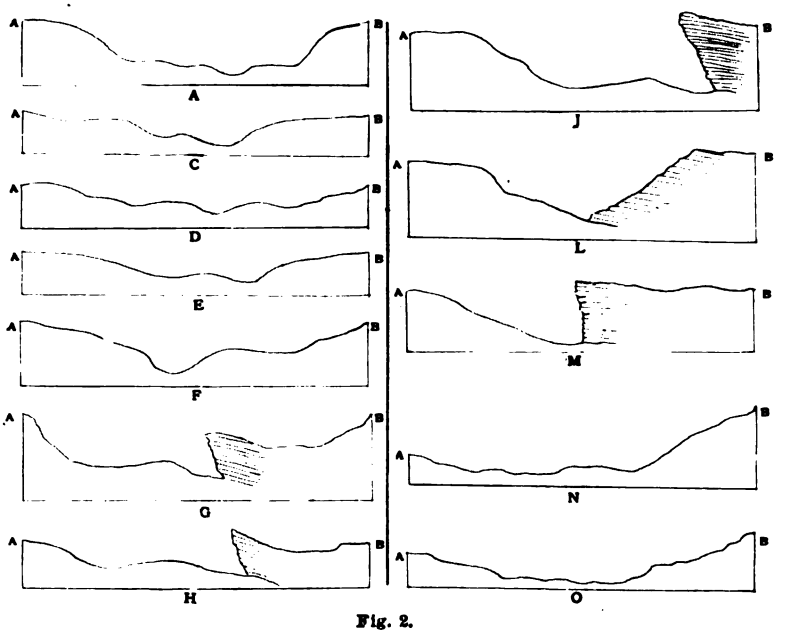

Fig. 2.

Our first stop was at (A). Two distinct courses were seen. The deepest of which was the one the brook occupies at present, and upon the map is (1). The next older is (2). In this, water is still to be found, but it is stagnant. (3) is still an older course. Here the land is marshy, but no water is present in the course. This marsh indicates that not long ago the brook occupied that course. (4) is the next older, while (5) is the oldest of all.

The bed of course (1), is composed of trap boulders, also fragments of sedimentary rock, but the latter are not as numerous as the former. These fragments are composed of shale, small pebbles of quartz, also pieces of feldspar and granite which have been brought down from above by the water.

The young or V-shaped valley is changing to one more mature. Here the descent is comparatively steep, causing many rapids. At the base of one of these a small pool still containing water may be seen.

In order to find the cause for the changing of course (5), as mentioned in (A), we stopped at the left bank of the brook at (B). The large root of a tree had grown across the channel of the stream. In this course (5) were seen small pools left there from the time the course was occupied.

The valley at (C) is more U-shaped or mature than below. Here the rock changes from trap to sedimentary, although boulders of the former may still be found.

There are three distinct courses on the left side of the brook at (4). The oldest of the three is (4); the next in age is (3); (2) is still younger, while (1) is occupied by the stream at present. The rocks in the bed are of more uniform size, being broken in large layers.

At (E) a stone wall was built across the brook, causing it to flow in two directions; (1A) flowing through the opening made for it; (1B) washed away some of the rocks of which this wall was constructed and then flowed on as tranquil as ever. The bed was very rocky and many boulders were seen. At the right of this stream is an old course now unoccupied. It is as low as, if not lower than, the present course, and is indicated as (2) upon the map.

At (F) the brook is running through a meadow. Course (1A), as mentioned in (E), flows along the left side of the stone wall, while (1B) does likewise upon the right. The bed is grassy and pebbly with sedimentary rock beneath. The brook flows away from the stone wall at (G), but the old bed continues the same. The stream has a marshy flood plain upon each side. At (H) the sedimentary rocks mentioned in (F) are now upon the surface. This sandstone dips about 25 degrees to the east. The strike was north and south. The brook flowed along this dip until the level of the meadow was reached. In one particular place the brook has so worn the rock as to form a large overhanging wall. The weathering of this wall is aided by the moss and other organic agencies growing in the crevices; the joints also aid by allowing the water to flow through them.

Fig. 3.

Locality H on map looking upstream, showing where the brook is cutting under the dip of the sandstone layers.

At (I) above the bend in the brook the rocks are softer than below. A small waterfall with its corresponding pool met our view. Because of the softness of the rock the water had so worn it that the dip could not be seen.

The rocks at (J) are harder than at (I), and also tilted at a less degree, and the former allowed the dip to be seen. The difference in hardness of the rock caused the brook to meander. The parallel jointings are plainly visible. They are about north and south, east and west, also northwest and southeast. The broken fragments again formed rapids in the course.

At (K) the large stump of a tree caused the stream to change its course more to the right. At high water this stump causes a waterfall, but now it is dry. In the small pool below is collected a pile of fine sediments. The direction of the jointing here is about southwest and northeast, also northwest and southeast.

Above (K) a portion of the rock is broken along the joint very smoothly. The sedimentary layers are dipping about 15 degrees to the east. Small pebbles are found in the bed. Upon the right side is a small marsh, also an old course.

At (L) a small side stream is seen to enter the main brook upon the left. This tributary contains water only in the Spring. The main brook has divided into three distinct courses, all occupied. The greatest amount of water is carried in the middle course. It is very marshy upon both sides of the stream. Upon the left side is a large accumulation of sediments, washed down by the water, from the road which is above.

From (G) to (N) the large hanging wall upon the right is very noticeable. The jointings of the rock in this wall are parallel.

A large pile of boulders were seen at (M). During high water they form a waterfall, but it is dry at present. Below this fall is a small water area or pool, within the center of which is a large accumulation of sediment. Here the bed is nearly level, that is, the sandstone of which the bed is composed has only two joints or breaks to mar its smoothness. A large crevice is noticeable in the hanging wall. In the joints of the crevices moss, ferns and flowers were growing which aided in the decay. The rapid weathering of this wall caused the wide valley at this place, while the depth was due to the slope of the land and the force of the water. In some places the jointing was at right angles. One large boulder and several smaller ones were found upon the left bank of the stream at (N). The former caused the stream to divide and flow upon each side of it. It also had caused the brook to deposit the large pile of sediment collected behind it. The jointing was parallel and also at right angles. Owing to the lack of force of the water, a large pile of sediment was deposited, the coarsest near each shore. At the center it was fine sand. If this was consolidated, it would be called conglomerate. For a short distance beyond this point, at (N), the brook flows parallel with the road. The third picture (Fig. 5) describes the view, looking down

Fig. 4.
Looking upstream from a point above M, showing the long descent to the pool at M.

Fig. 5.
Looking downstream, showing the sediments accumulated in the pool in the background.

stream to the deposit of sediment mentioned above. The second picture (Fig. 4) looks up stream from the foot of the long slope, which begins near this deposit of sediment, shown on the third picture, and takes in the pool at the base of the slope.

At (o) the valley seems to be a small meadow or marsh, due to the softness of the rock. Owing to this marsh there is a very abrupt curve or bend in the course below. The bed is grassy and the valley nearly

level at the source of the natural brook; that is, when we come to the dam of the small reservoir.

The Connecticut river from a point a short distance below Smith's ferry to the Canoe Clubhouse at Holyoke is acting just like the brook which has been described above. It is flowing along the strike and down the dip of the red sandstone layers. This portion of the river is known as the rapids and the bank on the western side dips gently into the stream and is formed of strata of sandstone. The peculiar jointing causes the rock to break into large slabs and the water coming in contact with the broken edges forms numerous whirls and eddies. On the other side of the river the edges of the tilted sandstone layers form a nearly vertical wall. The water off this bank is also deeper, as is also the case in the brook. The river here, owing to the slope, is actively cutting, but it is hindered in its action by the character of the rocks, which, while soft, have resistance enough to make the rate of down cutting a slow one. In a word, the brook and the river show the same features, only one is on a smaller scale than the other.

AN EXPERIMENT WITH ROGET'S SPIRAL.

BY C. F. ADAMS.

Instructor in Physics, Detroit Central High School.

Roget's experiment, as is well known, consists of a spiral coil or spring suspended vertically, so that its lower end just touches some mercury placed beneath. When an electric current is sent through the spring the mutual attractions of the several spirals shorten the spring, and thus break the circuit at the surface of the mercury; the attraction then ceases, and the spring lengthens by its own weight, thus re-establishing the circuit and causing a repetition of the motion. In this way a vibratory motion is maintained in the spring. While experimenting some time since with such a spring, I noticed a tendency toward the formation of a node near the lower end of the spring. This led me to experiment upon different springs of various dimensions and degrees of flexibility. The chief difficulty I met with was in establishing a simple vibratory motion, two or more rates of vibration usually combining in the spring to form a complex motion and thus obscuring the nodes.

One spring was made of No. 20 spring brass wire and was

about 2 cm. in diameter and 66 cm. long. In this spring a node was easily established at a point about 22 cm. from its lower end, while between that point and the upper end there was considerable amplitude of vibration. A strong current was necessary to maintain the vibration, five or six secondary cells being used, and very careful adjustment of the contact with the mercury was necessary.

Recently this experiment has been modified and more striking results have been obtained. A more slender spring has been used, one made of No. 22 wire about 2.5 cm. in diameter and a meter long when suspended, the spirals being about 5 mm. apart. The lower end of the spring was fastened to the hammer-rod of an electric bell, which was placed in such a position as to cause longitudinal vibrations in the spring. It was necessary to load the vibrator to reduce its rate of vibration; also to limit its amplitude by stops. One or two cells are sufficient to maintain the motion. With such an arrangement the number of nodes and antinodes maintained in the spring can be varied, the number depending on the adjustment of the vibrator. In the spring here described at times there were 10 nodes, sometimes 13, and again 15 nodes were maintained. At each node a single spiral of wire was almost perfectly stationary, while between the nodes there was a wide amplitude of vibration. The motion is striking and beautiful. It could easily be projected by a lantern on a screen.

This experiment is the counterpart of the familiar one with a rope, except that we have here longitudinal vibrations in an elastic medium, instead of transverse vibrations. It is especially interesting because it illustrates so perfectly the motion of the air in vibrating air-columns.

APPARATUS FOR EXPERIMENTS IN ELECTROLYSIS.

BY WARREN RUFUS SMITH.

Department of Chemistry, Lewis Institute, Chicago.

In Fig. 1 (No. 1) is shown an apparatus which has given good results in the hands of students. It is simple in construction and is made from materials which are obtainable from any electrical supply house. It is designed for use with the ordinary 110

volt lighting current. The details of construction are as follows:

The connection with the circuit is made with two brass plugs furnished with insulating handles. In many cases it would be found more convenient to replace these plugs by an ordinary screw attachment plug. To these plugs there is attached a piece of two-strand incandescent lamp cord leading to a block of wood. On the block are two binding posts and an incadescent lamp socket. One strand of the cord goes directly to the foot of one binding post and the other strand goes to the lamp socket and thence to the other post. To these binding posts is attached another piece of two-strand lamp cord terminating in two electrodes. These electrodes are made from coppered arc light carbons. One end of the carbon is fitted with a brass cap holding a screw carrying a nut and washer as shown in the detail drawing (No. 3). This cap

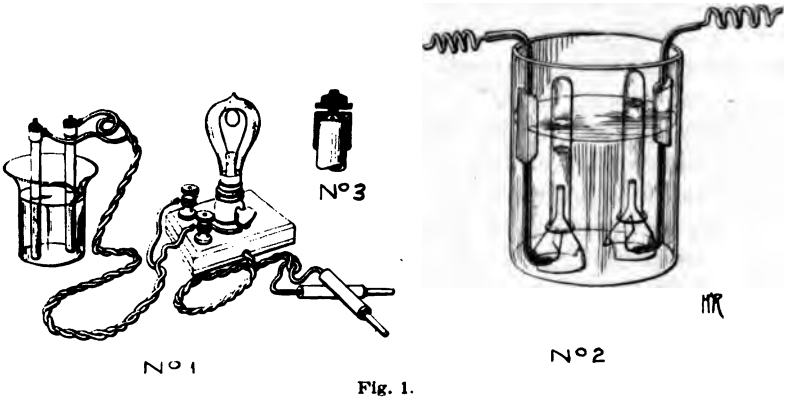

Fig. 1.

is soldered firmly to the carbon. This method of attachment allows the easy renewal of the carbon in case it is broken. The carbons are dipped in nitric acid to remove the copper coating and after washing are ready for use. The advantages of the lamp in the circuit are threefold. It serves as resistance, as a switch, and as a galvanometer. There are no bare wires or connections back of the lamp, hence it is impossible to get a short circuit with this arrangement so long as the insulation is unimpaired. The carbons

may touch without doing any damage and the shocks which students may get by handling them are harmless. Whenever desired, the lamp can be turned off, and then one electrode is "dead" and no current passes. Of course one electrode is always "live" when the apparatus is connected to the circuit, but the shock obtainable by grounding that is slight. The brightness of the lamp shows the amount of current, and hence the conductivity of the electrolyte. Results obtained in this way are always rough and only comparative at the best. However, they are sufficiently marked to illustrate many facts and principles, for example, the increase of conductivity with dilution.

The apparatus described above, while serving admirably for many experiments, is not suitable for those in which it is desired to collect the gases evolved. Fig. 1 (No. 2) shows a form of cell adapted to this purpose which can be made from ordinary laboratory material. The cell is a large battery jar. The electrodes are pieces of sheet platinum welded to short platinum wires. These wires are fused in the ends of glass tubes and are connected inside the tubes to ordinary copper wire.

This connection is made either by solder or by mercury. The glass tubes are bent, so that, starting from a point on the bottom of the jar midway between the center and the wall, they extend horizontally to the wall of the jar, then vertically up the wall, and finally horizontally over the edge. They are firmly attached to the walls by means of sealing wax. If the wires are connected by solder, the tubes should be bent and the wires connected and placed inside before the ends are fused around the platinum. If a mercury connection is to be used this is not necessary. Over each electrode there is placed a small short-necked funnel. The rim of the funnel is cut away slightly on opposite sides in order to allow the glass tube to pass on one side and to give a greater conductivity on the other. The cell is connected through the lamp to the lighting circuit as before. For use the cell is filled nearly full of liquid (e. g. dilute sulphuric acid) and test tubes are filled with the liquid and inverted over the necks of the funnels. The current is turned on and allowed to pass until sufficient gas has been collected. The current is then turned off and the gas tested or measured.

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

(*Continued from page 198.*)

EXPERIMENT VII.

To find the law connecting the distance of the observer with the apparent size of an object.

(a.) Place a globe, or other object, at a distance equal to 20 or more times its diameter, from the home-made plane table described above, and draw lines on the sheet of paper pinned to the board directed toward the opposite ends of a diameter, and measure the angle between them with a protractor. Then remove the globe to twice the former distance (at B) from the table and measure the angle again, then to three times (at C) the distance, etc. Tabulate the distances in one column and the measured angle in an adjoining column. Can you discover the law connecting the distances and the measured angular diameters? (See Fig. 9.)

(b.) A very good crude transit can be made by graduating to degrees (or to any desired accuracy) the arc of a circle struck with a center at a point about half an inch from the middle of one edge of an inch oak board, planed smooth on one side and sawed to about two feet length. Bore a half-inch hole at the center of the arc, and cut out another board one foot square from inch stuff, and after surfacing it on one side, graduate it also to degrees about a point near (about 1¼ inches above one end) one corner. Screw an alidade arm pointed at one end, and carrying

*For the convenience of those who may desire to use these experiments (there are forty-four of them) in their classes, they may be obtained in pamphlet form from "The School Science Press," Ravenswood, Chicago, at 25 cents a copy, and $2.50 a dozen.

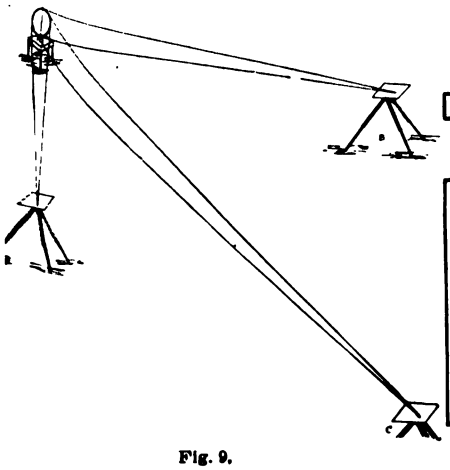

Fig. 9.

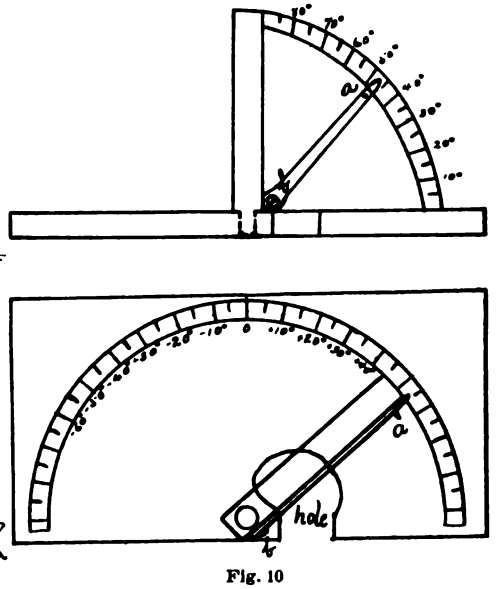

Fig. 10

Sharpened nails for sights, to this board at the center of graduation. Then cutting a spindle on the lower edge of the square board, so as to fit the hole in the first board, set the former so that it may swing freely about a line perpendicular to the latter board. The alidade being now free to swing about the screw at the lower corner, the measurement of vertical angles is made possible. To use the transit, set it on the top of the plane table described above, and level up as was suggested for the plane table. (Fig. 10.)

Problem—Execute the experiment (a) with this transit.

(To be continued.)

Metrology.*

THE CENTENARY OF THE METRIC SYSTEM.

BY JACQUES BOYER, in *Revue Encyclopedique Larousse.*

Translated by DR. WILLIAM H. SEAMAN.

(*Continued from page 218.*)

The report of this commission was presented to the legislature on June 22, 1799, at the same time with a platinum measure forged by the metallurgist Jannetti. This date is therefore the beginning of the metric system. Representations of the new measures were used to familiarize the public with them, the system attracted the caricaturists, and carpenters and geometers published manuals intended to teach it in a short time. Among the curious literature we may cite a dialogue between a capitalist and a real estate agent, read by M. Framery before the Philotechnic Society, the first of Floreal in the year XIII. Its object was to present in comic aspect the shocking complexity of the old measures used in the most ordinary affairs of life, and to bring out the advantages of the metric system. We give a part of it. The subject is the purchase of a piece of real estate by an investor, who visits an agent, with whom the following conversation is held:

Investor. I wish to buy 200 or 300 arpents of vineyard.

Agent. Very good, sir. But since you use the old terms, how large will you have your arpents?

Inv. What do you mean by how large? Is not an arpent always 100 square rods?

Agent. Yes; but all rods are not the same length; they change in counties, sometimes in townships.

Inv. What! not in this borough of Paris!

Agent. Oh yes, in the same village even. For example, in Brie there is the rod of 18 feet; that is the most common. There is also one of 18 feet 4 inches, one of 19 feet 4 inches, of 20 feet and of 22 feet. At Belleville, at Charonné, at Charenton-Maurice, at Nogent, etc., there are two kinds of rods. There are three at Pantin, and five in the county of Vincennes; in fact, there are five kinds of rods in this department.

Inv. That is frightful. Is there no way out of this chaos?

Agent. It will be found by the establishing of new measures to which there is no opposition and which, referring everything to one invariable standard will secure everywhere the most desirable uniformity.

Inv. Truly you incline me to this system if I had time to study it. But now to our business. I want to be near the river.

Agent. I know of two plots of about 300 arpents, to speak your language, that would suit you; the area is nominally the same, but actually very different.

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*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

Inv. No matter, the price is undoubtedly according to the real size. Now, I would like to know exactly how much wine they will yield; for instance, just how many barrels did they make last year?

Agent. If you want to be precise, do not talk about barrels, they are never exact. Perhaps we shall understand each other if we use pints. But here we shall get lost if we stick to the old style. There is the pint of Saint Ouen of 47 cubic inches, and the pint of Nogent of 74.

Inv. Yes, that is what they call the measure of Saint Denis, but if there are five kinds of rods, there are only two pints.

Agent. Oh, you are mistaken. First, Saint Ouen has its pint of 47 cubic inches, and is close to Epinay, where it is 74, and then there is the Dubeaugey pint of 69, and the big chapter is 70 and the little chapter is 66. These may not be all in use, but in Bercy close to Faubourg Saint Antoine, they have three, one of 47, one of 74 and another of 79 cubic inches.

Inv. And how much grain will these plots grow?

Agent. That is easy to find out because except in Saint Denis the bushel is the same throughout the department of the Seine.

Inv. That is fortunate.

Agent. Grain is measured by the *muids*, equal to 12 septiers, each having two mines, and the mine has two minots, and the minot contains three bushels, then the bushel is divided into the half, the quarter, the eighth, and the liter, which is the sixteenth part, and which is also divided into halves, quarters, and eighths, and also the small measure, which is the sixteenth part of a liter.

Inv. But how can I keep all these in my head?

Agent. I don't know, since you are frightened at the twelve words that express the whole of the new system for every kind of weight and measure.

Inv. Well, let the bushel go. I want to have a little wood on my place. How much a year will the land you offer me cut?

Agent. That is according to the length of the sticks.

Inv. Why, the ordinary length, of course.

Agent. That is 42 inches in this department, but in Pierre-fitte the brigot, as they call it, varies from 24 to 30, and in Branches du Pont it is 48.

Inv. You will drive me crazy with your confusion of measures. How long do you suppose it will take to learn the new ones whose names even are not familiar?

Agent. If you were 15 or 16 years old a couple of days would suffice, but at your age, full of business and pleasure, if you will give an hour or two a day, I think it will take you about a week.

Now let us return to the serious history of the meter. Méchain at the beginning of the century proposed to extend the meridian to the Belearic islands instead of stopping at Barcelona. Since Dunkirk and Fromentera are situated equally distant from the mean parallel of 45 degrees, this would avoid any error arising from the flattening of the earth at the poles, and hence a more exact measure for the standard could be obtained. Unfortunately Méchain died of fatigue and fever before finishing his undertaking, and the Bureau of Longitudes charged Biot and Arago with its continuance. They ran many perils trying to push their triangulation into Africa, but they did not reckon on the pirates, who kept them prisoners many months. However, they did not lose the results of their work, and after a forced sojourn in Algiers, Arago landed at Marseilles on July 2, 1809. It was not deemed best to alter the meter of the archives already finished; the correction required by the new results would have been insignificant, and the system having been legally adopted on November 2, 1801, it would have caused complications.

Nevertheless, the old measures continued in use among the common people till the monarchy of July, when on June 12, 1837, the Marquis Laplace presented to the Chamber a report, which concluded by prescribing that from January 1, 1840, all weights and measures except those established by law and constituting the decimal system should be forbid-

den. From that time it became a part of our customary usage, and as it is said that in France everything ends by a ballad, we add some verses of a "Complaint of Our Weights and Measures," which was peddled around the Capital. The imitation will suffice to give an idea of this doggerel, which owes its interest entirely to the date of its appearance. Whether these trifles contributed to popularize the measures or not is difficult to say; anyhow the new system was adopted without difficulty, and for thirty years, like happy nations, the meter has had little history. But from the date of the Convention of 1875 it entered on a new phase, that of becoming an international standard.

HOW TO LEARN THE NEW MEASURES. PARIS: 1840.*

Lengths.

Now come, ye architects,
Whose brilliant ideas vex
Your souls, and hark to me.
No inches more shall be;
Just throw away your two-foot rules,
And take your meter with your tools.

Liquids.

The measures of the ancient sort,
By which we've often sold and bought—
The barrel, gallon, quart and gill—
Will never more their purpose fill.
You now must learn to use the liter;
For less, the cubic centimeter.

Weights.

Now we'll talk in kilos and grams;
No longer use the pounds and drams,
At least, if we're intelligent.
Those old weights are obsolescent.
Grams to a kilo one thousand require,
Kilos for tons the same I desire.
When the new method is well in hand,
And the old forgotten in our land,
All will wonder, in days then past,
Our barbarous system so long should last.

About the time the system was established in France it was also adopted by Belgium, the Low Countries, and Greece. In 1862 M. Eward persuaded the British Chamber of Commerce to inquire into its adoption by England. Shortly afterwards Italy, Switzerland, Greece, Belgium and France signed a monetary convention in 1865, and the next year the United States recognized legally the existence of the meter.

In 1867 the international character of the meter became more pronounced. The Academy of Sciences of St. Petersburg passed a resolution, approved by the Czar, in favor of the metric system, and at the same time the International Geodesic Commission adopted the following important resolution: "In order to define a common unit of measure for all European countries we recommend the construction of a new European prototype meter." "The length of this standard should differ as little as possible from the meter of the Archives, and in any case should be exactly com-

*This song was published by Escudier, 127 rue de Bac, Paris, 1840.

Biot (1774-1862).
Facsimile of an engraving by Ambroise Tardieu.

Marquis de La Place (1740-1827).
Facsimile of an engraving by Delaistre, after Guillaminot.

pared with it. The construction of the meter and its copies should be in charge of an international committee in which all states interested should be represented." Shortly afterward the French government took the initiative and convoked the International Commission of the Meter which met at Paris on August 8, 1870. Notwithstanding the absence of England and Germany and the interruptions to travel caused by our misfortunes, the delegates, before separating, while postponing the final decision to a more favorable time, discussed the principles on which the new prototype meter should be made. Again called together in 1872, the Commission enlarged its program to include other parts of metrology and especially to an investigation of the kilogram. The French section of the Commission was particularly active in the next few years. H. Deville studied the metals of the platinum group and caused the adoption by the Convention of an alloy of platinum and iridium as the material for the unchangeable prototype standards. Its fine grain, its hardness, its resistance to moisture and oxidation, places it in the first rank of substances adapted to furnish irreproachable standards. The learned chemist was aided by his brother Charles, and by the physicist Stas, Belgian delegate to the conference. After ten years of labor they succeeded in bringing these metals to a state of remarkable purity. "These prototypes," exclaimed J. B. Dumas, "will endure for centuries, even though they may be exposed to dry or to damp

ARAGO (1786-1853).
Facsimile of a lithograph by Julien.

General MORIN (1795-1880).
During the Commune he saved the standar from destruction.

air or plunged into the sea. They will come out of the most violent conflagration unharmed and can only be injured by intentional violence, such as the blows of a sledge or the action of lime." In 1874 by means of a special furnace they melted at one time 250 kilograms of platinum iridium. This was no child's play, and then Stas proceeded to make numerous delicate analyses to be assured of the composition of the alloy, while Deville determined its density with rare precision to find if any blow holes or cracks existed in the ingots, the only way the homogeneity of the ingot could be determined. In addition Tresca determined the shape of a bar required to possess the necessary rigidity, and Fizeau, aided by his method of interference, showed how small was the coefficient of expansion. This was important because it reduced the probability of errors in temperature corrections. During this period the governments represented at the Convention were not idle. They gave legislative sanction to the work of the *savants,* without which a unification of measures could not have been accomplished. The celebrated Convention of the Meter was signed at Paris May 20, 1875, and simultaneously ratified by sixteen states, Germany, Austria-Hungary, Belgium, Argentine Republic, Denmark, United

CHARLES and HENRY SAINT-CLAIRE DEVILLE in 1864.

STAS. (1813-1891). Facsimile of an engraving by Danse.

States, France, Italy, Peru, Portugal, Russia, Sweden and Norway, Switzerland, Turkey and Venezuela. They also agreed to support at common expense the International Bureau of Weights and Measures, a scientific organization to be located at Paris. Its operations were to be under the exclusive direction of the International Committee, itself subject to the authority of the General Conference of Weights and Measures composed of delegates from the contracting states. The Committee has met regularly up to the present time, and the Conference has held two sessions, in 1889 and in 1895.

The International Bureau of Weights and Measures, its establishment and its scientific material. The International Commission of 1872 prescribed the principal features of an extensive program to be executed by the physicists of the International Bureau.

The international meter was to be a copy of the meter of the Archives "as it is," and also the kilogram was to be deduced from the kilogram of the Archives. At this point the theoretic men made certain criticisms. They wanted to begin over again with the ideas that inspired the founders of the metric system, and obtain a more exact measure of the ten-millionth part of one-quarter of a meridian by new geodetic measurements and correction of the old prototype.

This was Utopian, for if in twenty-five years with better instruments and extreme care the measurement of the meridian might be made a little more precise, it would still be only an approximation to theoretical accuracy, and it was much wiser to do as the men of 1872 had done, and not commence an endless series of alterations as geodetic methods improved. But many other difficulties were to be overcome to accomplish the work required, to collect the necessary apparatus and install it in a suitable location. The government assisted by vesting a free title in the Committee to the pavilion of Breteuil, the ancient summer residence of the Princess Matilde, in the Commune of Sevres (Seine et Oise), in the middle of a park of venerable trees. Here there are no vibrations such as are caused by the traffic of a great city, and all the conditions are found that are desirable for such an establishment. This appendage to the Chateau of St. Cloud was in ruins, and the first years were spent in re-

The International Bureau of Weights and Measures at Sevres. (Seine et Oise).

building the old and erecting new buildings suitable for the work. We cannot here describe all the arrangements found necessary, but the first instruments were not set up till 1878. They rest on pillars of masonry firmly bedded in the ground. These massive pillars are independent of the floors of the buildings, and so arranged that observations may be made free from errors caused by the proximity of the observer.

We may now inquire what apparatus the International Bureau uses for making measurements, and what work it has already accomplished. First, for measuring length, there are four comparators. These consist

Medal commemorating the Conference of the Meter (1872). Engraved by Chaplain.

essentially of two fixed pillars carrying microscopes provided with micrometers, under which are brought by peculiar mechanism the two scales which are to be compared.

(*To be continued.*)

Notes.

PHYSICS.

The Violet-blue Color of the Electric Arc can be made more yellow by impregnating the upper carbon with calcium or magnesium salts. As it burns more rapidly than the pure carbon rod, it must be made larger in order to last as long.

High Voltage Underground Cable. An underground cable three miles in length at St. Paul, Minn., has recently been successfully tested at 30,200 volts, the highest voltage hitherto obtained with this class of conductors being the 20,000 volts used at Niagara Falls. The cable at St. Paul consists of three copper conductors, each wrapped in paper and the whole encased in lead and laid in vitrified clay conduits. As a result of this test 5,000-horse power at 25,000 volts will be transmitted from Apple River, Wis., to St. Paul, a distance of 27 miles.

The Frequency of an Alternating Current may be measured by the following simple and convenient method: A disk covered with narrow black and white sectors is rotated before an incandescent lamp through which the alternating current whose frequency is to be measured, is passing. The speed of rotation of the disk is varied until it appears to stand still. Then the product of the sectors of one color by the number of revolutions per second gives the number of reversals per second of the current, or twice the frequency. Of course, it may happen that the disk may be revolved at two or more times the proper speed with the effect that it appears to be at rest. In that case, a multiple of the frequency is obtained.

Convenient Mercury Cups may be readily and cheaply made as follows: A cork about two cms. or more in diameter is pierced with a hole about a cm. in diameter only half way through. The cork thus perforated is glued in the middle of a shallow cardboard box, such as those in which Denison's gummed labels come. The cavity in the cork is then half filled with mercury, in which the wires making the electrical connections may be dipped and held in place quite firmly by thrusting them into the cork. The box cover not only gives the cup steadiness, but also acts as a tray to catch the mercury that may be spilled out.

How Welsbach Mantles Are Made.—A six-cord cotton thread is woven on a knitting machine forming a tube of knitted fabric of rather open mesh. This web has the grease and dirt thoroughly washed out of it, is dried, then cut into lengths double that required for a single mantle. It is then saturated with a solution made from monazite sand, which yields in the finished mantle the oxides of thorium and cerium, wrung out, stretched over spools and dried. Next the double length prices are cut into two, the tops of each piece doubled back and sewed with a platinum wire which draws the top in and provides a means of supporting the mantle when finished, from the wire holder. After stretching the mantle over a form, smoothing it down, and fastening the platinum wire to a wire mantle holder, the mantle is burned by touching a Bunsen burner to the top. The cotton burns off slowly, leaving a skeleton mantle of metallic oxides, which are unconsumed, and which preserve the exact shape and detail of every cotton fiber. The soft oxides are hardened by a Bunsen flame. During burning out and hardening, considerable shrinkage takes place. The mantle is finally immersed in crystalline to prepare it for transportation, and packed.

GEOLOGY.

The Flow of Rocks.—Prof. Frank D. Adams, of McGill University, has recently shown that rocks may be made to flow by subjecting them to enormous pressures. Marble was used in most of the experiments. Cylinders of it were fitted into wrought iron tubes of great strength, in

either end of which played heavy steel cylinders. The marble was then subjected to pressures of nearly a hundred tons per square inch, often for several months at a time. The iron tubes were found to bulge out, and when they were cut away blocks of solid marble were obtained, which had changed in shape considerably and which were only about half as strong as originally. If, however, the pressures were applied while the marble was heated up to temperatures of 300 degrees C. to 400 degrees C., it flowed much more readily and the resulting block was but little weaker than the marble taken.

Ocean Depths.—The "Outlook" publishes under the authority of Professor J. E. Jenks, one of the editors of the "Army and Navy Register," the discovery of a greater depth in the ocean that has hitherto been recorded. The vessel Nero, engaged for the last few years in surveying a cable route across the Pacific, has reached a depth of 5,269 fathoms and 5,160 fathoms at a point between the Midway Islands and the Island of Guam, a little east of the latter. Previous soundings in the same region had shown a depth of 4,900 fathoms. At 5,070 fathoms there was a temperature of 39.5 degrees F. and at 5,101 fathoms 36 degrees F.

A submarine range of mountains was also located between Guam and Yokohama, connecting the range that was known to exist between Japan and the Bonin Islands with the Island of Guam. A large peak on this range, comparable to the peak of Fusiyama, reaches within 480 fathoms of the surface.

Two Pamphlets of very considerable interest to instructors in geology and physiography appeared last summer. These are: *Profiles of Rivers in the United States,* by Henry Gannett, being No. 45 of "The Water Supply and Irrigation Papers" issued by the Geological Survey, and *A Guide to Geology and Paleontology of Niagara Falls and Vicinity,* by A. W. Grabau, Bulletin 45 of the New York State Museum.

The first of these contains eleven plates illustrating the slope of 100 rivers of the United States, with about 100 pages of descriptive text. In the text we find information as to the source of the river, its extent and the character of its drainage basins, details of slope, etc. In a table accompanying the description are given details as to the distance from the mouth, the elevation above the sea and the rate of fall per mile at important towns in the course of the stream. The plates are drawn with a horizontal scale of 100 miles to the inch and a vertical one of 2,000 feet to the inch. This gives the streams of the coast ranges a seemingly exaggerated steepness of slope, while the Mississippi river shows no apparent fall for many miles from its mouth; but the advantages in the use of a single scale for all rivers is evident. The pamphlet will be of great use to the teacher of physiography in illustrating comparative lengths and slopes of streams; also the relative steepness of slope at head and mouth of rivers. The effects of rejuvenescence, of local geological barriers and

other points in the history of the stream are splendidly shown if the plates are considered in connection with appropriate maps. The pamphlet may be obtained free by applying to the Director of the United States Geological Survey.

The second pamphlet has been prepared as a guide to Niagara Falls for the visitors to the Pan-American Exposition at Buffalo; its 286 pages are divided into five chapters, with an introduction and appendix. The first three chapters treat of the physical geography of the Niagara region, the life history of the Falls and the stratigraphy of the region; this portion is illustrated by fourteen good plates, showing scenes of the falls, gorge, etc., and thirty-four text figures showing details of structure. Accompanying the Bulletin is a large-size map, covering geologically the region from Buffalo to Lake Ontario. The last two chapters describe the fossils of the Niagara region and the Post-Pleistocene fossils of the Niagara River gravels; 190 figures of fossils are given. The appendix contains a valuable bibliography of the falls and a glossary of geological terms. The pamphlet may be obtained from the Director of the State Museum, St. Albany, N. Y.; its price is 65 cents.

Book Reviews.

Elements of Astronomy. By SIMON NEWCOMB, PH. D.; LL. D., formerly Professor of Mathematics and Astronomy in Johns Hopkins University. 13x19 cms., 140 pages. American Book Company, Chicago. $1.00.

This pleasing little volume attempts merely an untechnical presentation of those facts and laws of astronomy which are of most interest and importance to the general public and, in the execution of this attempt, to avoid as far as possible the necessity for formal mathematics. For the general reader both these objects are certainly praiseworthy; but for instructional purposes in the public schools there is place for legitimate difference of opinion as to whether the prevailing and growing custom of eliminating from text-books in the semi-mathematical subjects of physics, astronomy, etc., designed for the elementary and secondary schools, substantially everything involving mathematics is not in great danger of enervating the scientific work of these curricula by the presentation of fragmentary and distorted, if not spineless, views of the sciences. This tendency has already been carried so far that schoolmasters show a disposition to regard only the qualitative aspects of science as of any value,

or importance, in instruction and to look upon the introduction of its quantitative aspects as the lugging in of an artificial something to serve merely, or mainly, as the foundation for the teaching of mathematics. This tendency is, of course, regrettable in the extreme.

The reputation of the great author of this book is sufficient guarantee of its excellence both as a popular and accurate scientific presentation of the substance of the science. Rare sagacity and deep discernment are manifest throughout, both in the choice of representative topics and in the order and manner of their elucidation. This little book is another of the many proofs the scientific reader has had of late that Professor Newcomb possesses to an eminent degree the rare faculty of being able to condense the results of science without squeezing the juice out of them, of being interesting and at the same time scientific.

The publishers have maintained their high reputation as text-book makers both in the cuts and in the typography. Among those who sympathize with the reduction of mathematical demands in elementary science teaching to a minimum this book will doubtless secure the wide adoption it deserves.

G. W. M.

An Elementary Treatise on Qualitative Chemical Analysis. By J. P. SELLERS, A. M., Professor of Chemistry, Mercer University, Macon, Ga. 19x13 cm., 157 pages. Ginn & Co., Boston, 1900. 80 cents.

The author of this book aims to avoid unnecessary details as well as extreme condensation. It is a modern book. In addition to a judicious selection of qualitative methods, the book contains seventy-five pages devoted to the theory, methods and systems of qualitative analysis, the application of the theory of ions to qualitative reactions, and a brief treatment of spectroscopy. These topics are clearly treated and adequately illustrated by experiments and diagrams. If any criticism were to be made of these features, it is that the treatment is too condensed for a beginner and too brief for an advanced worker. On the other hand, the author is to be commended for incorporating such needful matter into a book which is the bridge from general chemistry to quantitative analysis. Another new feature is the application of Reddrop's system of normal solutions to qualitative work. The methods of separation are often duplicated, and the student is encouraged to exercise his judgment in selecting the best method. Mechanically the book is most praiseworthy. This fact will contribute materially to the design of the author, viz., to provide "a course short enough to be digested during the time allotted in an ordinary college curriculum."

L. C. N.

Introduction to the Study of Zoology. By N. A. HARVEY, Head Department Science, Chicago Normal School. 13x19 cms., 208 pages. Western Publishing House, Chicago. 88 cents.

This book is written from a pedagogical standpoint and shows clearly

the value of zoölogy as a teaching subject. The author has shown that zoölogy is the most logical of high-school subjects, and if the greatest benefit is to be derived from it, it is one that throws a great strain on the student. Zoölogy taught from a developmental standpoint will also change the teacher's attitude and make him present the subject in a clearer way.

The first part of the work is on the insects. Different types of these are used to represent different families. The resemblances of these Families are brought out by the student and the idea of an Order developed. Then types of Orders are studied, and from these the conception of Class is drawn. Next the idea of Branch is developed and, as a final step, the student is brought to the knowledge of the essentials of an animal. But in order to do this the student has had to keep in mind, in usable shape, all the work of the year.

The laboratory outlines, which make up the greater part of the book, are very good, the best that the writer knows. They are not too full to tire a high-school student and are full enough to develop the subject clearly. They give what is needed—a clear, first-hand knowledge of the type specimens studied.

Several other features of the book are very good. Under the head of additional facts the author has added enough material not obtainable by the student during the laboratory period to take the book out of the list of pure laboratory guides. With the aid of these statements and by judicious questioning he has developed a considerable amount of animal ecology, without giving it that specific name. His development of Von Baer's principle is excellent, and will be quickly grasped by the average high-school student. The general hints on collecting are very useful. The analytical keys appended are an excellent feature and show that such work can be done in the high school.

The writer believes that the book would have been helped by the addition of a little bibliography.

The book is an excellent one for high schools and academies and deserves a wide use.

Kansas City Central High School.....PORTER GRAVES.

The Elementary Principles of Chemistry. By A. V. E. YOUNG, Professor of Chemistry in Northwestern University. 13x10 cms. XIV. and 252+106 pages. D. Appleton & Co., New York, 1901. $1.10.

The method of beginning the study of chemistry by having the student get his knowledge first-hand in the laboratory is becoming more and more popular every year, especially as the obstacles to laboratory equipment are being surmounted. The book at hand carries out this method in its entirety; the student performs "the experiment illustrative of a topic before he gives attention to the fuller presentation of the same in the text." The book is accordingly divided into two parts, the first part con-

taining the text and the second, the experimental illustrations. By a system of marginal numbers the two parts are brought into close connection.

Many of the experiments are quantitative, but do not on that account demand an extensive laboratory equipment for their successful performance. Quantitative work is indeed necessary to illustrate the fundamental laws and principles of chemistry, and anyone teaching *chemistry,* and not wholly *chemicals,* will allow this claim. As the title of this book implies, it is mainly devoted to the underlying principles of the science, and yet there is enough matter of a descriptive kind to cover what is usually given in elementary courses.

Books based on laboratory methods and quantitative work may indeed be considered by some teachers to be too difficult. This difficulty is not, however, one that the pupil has, but one that the teacher has. A poorly prepared teacher cannot teach well according to the laboratory methods, where he is, so to say, right in the presence of nature, however fine a showing he can make by text-book methods. The adoption and use of a book of this nature is in a way a testimonial to the ability of the teacher. While this book is perhaps above the average teacher, it is not above the average student. To help the teacher to teach his book, Professor Young has in a "Guide" gone over the subject matter in detail and in a most thorough and personal way. These "Suggestions to Teachers" form a most valuable course for the chemistry teacher, either embryonic or mature. He will find in it much that is clear and suggestive, and that will give him considerable help in his teaching. As a book for teachers this chemistry takes high rank.

One of the most admirable features of the book is the breadth of view manifested; chemistry is not regarded as isolated, but as wrought into an integral whole with other branches of knowledge. Humanistic touches here and there also vivify the subject matter, and the excellent reproductions of the portraits of the founders of the science contribute to interest and hold the student. Its "culture value" is also great. The strictness of logic employed in passing from facts to laws and from laws to theories, the nicety of choice in the experimental illustrations and the fair, almost "legal" definiteness and clearness of statement stamp this book with a worth peculiarly its own.

C. E. L.

The Metric System. By S. Jackson, M. A., with an Introduction by J. Emerson Dowson, M. Inst. C. E. Allman & Son, Limited, 67 New Oxford Street, W. C., London. 1900. 99 pages.

The design of this book is to aid in the introduction of the metric system in England. There are two ways, the author remarks, in which this important reform can be helped along—first, by teaching the principles and facts of the system in the public schools; second, by showing its advantages to those engaged in commerce and trade. The book aims to cover both

these points. Part I treats of metric principles, arithmetical notation, calculation of prices, etc.; Part II, of practical details—length, area, volume and weight, applied to various trades; Part III, of decimal coinage—a reform very much needed in Great Britain. The superiority of decimal weights and measures can in no way be better[2] appreciated than by contrasting the awkwardness of computing values by English pounds, shillings and pence, with the perfect simplicity of our own decimal money. Let any American carefully study Part III of this book, and if he doesn't become a convert to metric weights and measures his case is hopeless.

The principles of the system are clearly defined. From the simplest facts of notation to the most complex calculations the progress is by easy steps. The work is without illustration—except half a dozen geometrical figures—a noticeable defect. There are no answers to the exercises. The customary metric abbreviations are mostly omitted. *Centare* is written *centiare; kilo* is *kilog.* The French spelling of *metre* is employed and the English of *gram.*

In surveyors' measure a strong point might have been made of the decimalization of the chain—about the only decimal thing of which the English people can now boast, except in science. Computation of weight from volume, by use of specific gravity, would also have been a valuable addition.

There is an excellent table of modern coinages, which shows all nations except the United Kingdom, Australia and India, users of decimal coinage. A similar table of weights and measures exhibits the almost universal adoption of the metric system. Japan is classed as a *metric* country; *decimal* would be more accurate.

The exercises cover all sorts of arithmetical problems. To us it seems odd to read of the *stone,* the *kilderkin,* and of *oldish* hay in distinction from new hay and old hay. As a whole the book is an excellent *arithmetic of the metric system,* with just enough history and statistical matter to make it interesting.

R. P. W.

The Plant Societies of Chicago and Vicinity. By Dr. Henry C. Cowles. 18x26 cms., 76 pages. The Geographic Society of Chicago. 1901.

This pamphlet forms the second bulletin of the Geographic Society of Chicago. It is divided into three parts, of which the first contains a short discussion of the principles of classification of plant societies; the second a consideration of such societies as are found in this region, and the third a list of the localities about Chicago which are of interest botanically, together with the plant societies which may be studied in each.

The author points out for the first time the intimate relation which exists between the plants of a given area and its topography; further that, as a topographic form is altered by erosion and weathering, a corre-

[2]Review of S. J.'s Met. Sys.

sponding change takes place in the vegetation; and that just as a base level is the final result of erosion, so a mesophytic plant society is the climax stage in the floral history of a region. Whether the plant cycle exactly corresponds with the erosion cycle depends upon a number of factors, of which climate, latitude and soil are the most important. Here then is a basis for the classification of plant societies which is at once natural and adequate, and which takes into account the gradations between the various societies.

Of general interest is the discussion of the plant societies of the Chicago region. These have been divided into two groups: the Inland and the Coastal. Under the first head three series are considered: (1) the River Series, with its development from the ravine to the flood plain stages; (2) the Pond-Swamp-Prairie Series, and (3) the Upland Series. Of the Coastal Group the Lake Bluff Series and the Beach-Dune-Sandhill Series are discussed.

Although the plants named in this paper are those found about Chicago, nevertheless the consideration of the factors which control the distribution is taken up on such broad lines that it will be invaluable to botanists outside of Chicago, and of much interest to general readers everywhere.

To teachers of elementary botany it suggests a line of work which will supplement the laboratory instruction, and instead of the dry bones of plant analysis will afford the pupil a living subject for observation and study. It is an exposition of a relatively new line of botanical work—a line which is destined to become a leading one in elementary and secondary schools.

W. W. ATWOOD.

Books Received.

A Laboratory Course in Plant Physiology, especially as a Basis for Ecology. By William F. Ganong. Henry Holt & Co., New York, 1901. vi and 147 pages.

Introduction to the Study of Zoology. By N. A. Harvey. Western Publishing House, Chicago, 1901. 208 pages. 88 cents.

Lincoln in Story. Edited by Silas G. Pratt. D. Appleton & Co., 1901. 224 pages. $1.00.

Science Primers. History of Philosophy. By Thomas Hunter. American Book Co., 1900. 128 pages. 35 cents.

A Brief Course in General Physics. By George A. Hoadley. American Book Co., 1900. 463 pages. $1.20.

Elements of Astronomy. By Simon Newcomb. American Book Co., 1900. 140 pages. $1.00.

CLEARING HOUSE.

Teachers desiring to offer for exchange books, apparatus, etc., may insert a notice to that effect at the nominal rate of one cent per word, *in advance*.

Reports of Meetings.

N. E. A. ROUND TABLE CONFERENCE ON ZOÖLOGY.

THURSDAY, JULY 11, 3:00 P. M.

Dr. Franklin W. Barrows, Central High School, Buffalo, N. Y., *Leader.*
Grace F. Ellis, Grand Rapids, Mich., *Secretary.*

The leader, in proposing topics for discussion, presented the following:

Theses on Zoology in Secondary Schools.

1. Laboratory and field study should form the basis of the entire course and should be allotted at least half the time of the course.

2. The most profitable study of any organism takes into account not only its actions during life, but also its structure, both internal and external, as revealed by dissection.

3. Every student of zoölogy should practice the use and application of the compound microscope.

4. No plan has yet been devised by which zoölogy classes in cities can do even a fair amount of field work.

5. Since the pupil cannot go to the animals, the animals must be brought to him; aquariums and vivariums should be the centers of interest in every laboratory.

6. A liberal use of photographs, lantern-slides, charts, and illustrated books will economize both time and effort. Museum specimens and anatomical preparations are useful for the same reason.

7. The subject of economic zoölogy is of transcendent value and should be prominent in every course of study. The career of the English sparrow and gipsy moth in this country and of the mongoose in Jamaica, the importation of insects to the Pacific coast to fight the orange scale, and of others to fertilize the fig-trees, these are not only interesting zoölogic episodes but important economic revolutions. The life histories of mosquitoes, flies, tape-worms, the trichina, and the close association of these and other pests and parasites with diseases of man and domestic animals should be matters of common information in all our schools. So,

also, the valuable services of many despised animals, such as toads, snakes, and birds, should be thoroughly taught.

Mr. Murbach, of Detroit, was called upon to open the discussion, and in response said that to him the most important subject was that referred to as No. 2 of the theses. He referred to the much-discussed subject of dissection. He thought that dissection properly taught did not encourage cruelty in children, and considered a moderate amount of it indispensable. The objections of pupils to handling animals are decreased by beginning with the lower forms. Time may be saved in the study of some forms by the use of dissected preparations in the laboratory. At present there seems to be a reaction in favor of less dissection.

Mr. W. H. MacCracken, Buffalo, N. Y., believed that it was a mistake to expect the beginner in zoölogy to pay much attention to minuteness of detail in dissection. In place of the fine points of anatomy often insisted upon, he favored a few simple demonstrations of function by vivisection.

Principal Wm. J. S. Bryan, Normal and High School, St. Louis, Mo., attributed to lack of experience the repugnance of pupils to handling most forms of animals. When interest has been aroused this aversion is removed. Mr. Bryan asked, "How much use of the compound microscope is profitable? Will a simple lens answer all purposes?"

The leader, in reply, said that the pupil should first be trained to use his own eyes "for all they are worth." After this he should acquire the power to use the compound microscope because the instrument may be of great service to him in the future. The technic of the instrument is simple, and no school should deprive its pupils of the practice necessary to make them independent in its use.

Mr. Murbach, in response to a question, gave a brief outline of the course in Detroit and said the present tendency is to emphasize somewhat the living animal by such harmless experiments as tying the fins of a fish in order to learn their function, or studying the earthworm in glass tubes or cases filled with soil.

Mr. MacCracken approved the course just outlined rather than one which devotes the whole time to the study of one or two types. He quoted a student who had passed through such an experience and complained that "for him, zoölogy had too much *froginess.*"

Another teacher said her experience proved that repugnance to handling animals could be largely overcome, and that in her estimation experiments with living animals were extremely valuable.

Some other theses were then briefly touched upon, Nos. 5 and 6 being emphasized in order to overcome the difficulty mentioned in No. 4.

Mr. MacCracken distributed some photographs of birds and fowl taken by himself, and at the request of the leader, read a paper on "The Camera in Zoölogy." In his opinion, camera views presented many advantages over drawings as far as accuracy is concerned. Mr. MacCracken also

thought that drawing did not always tend to more accurate observation of an object, and that scientific photography, while by no means fully developed, afforded great possibilities for scientific information and research.

N. E. A. ROUND TABLE CONFERENCE IN PHYSIOLOGY.

THURSDAY, JULY 11, 4:30 P. M.

In the absence of Mr. Jas. E. Peabody, teacher of physiology in Peter Cooper High School, New York City, and leader of this conference, Pres. W. J. S. Bryan took charge. He spoke of the bearing of physiology on every-day life, the time to be given it in school, and said:

"Physiology has long been accorded a place in the high-school curriculum; its importance has been recognized. But those who have taught it have not yet devised means for its teaching by the methods now regarded as essentially scientific. That the same can be done for physiology as has been done for botany and physics and chemistry is not to be questioned."

After this, Mr. L. Murbach, of Detroit, was called upon and spoke along the line of laboratory work and the laboratory methods in physiology. "While it is difficult to treat human physiology in the high-school by the laboratory and experimental method, the combination of physiology, hygiene, and sanitation can be thus treated. This is, in any case, a good combination for the high-school subject to be known as physiology. Much stress should be laid on teaching at least half the subject by the laboratory method. This is best done in connection with the text, or rather to precede its use. The function of blood, for example, should be preceded by the observation of blood-vessels in a live earth-worm and then in a frog's foot. Physiology, when thus taught, should be recognized by higher institutions as equivalent to the same amount of other biological training."

Mr. S. B. MacCracken, of Buffalo, emphasized what had been said about laboratory work in physiology, and showed the help gained from getting pupils to study their own bodies, muscles, etc. That actual specimens should be studied, for human anatomy, even as given in Gray, is not exactly like specimens.

Miss Grace Ellis, of Grand Rapids, spoke of simple, home-made apparatus, and described a spirometer. Her pupils learned some interesting things from it, as lung capacity. The knowledge was applied in proper exercise, and the capacity of the lungs increased, as shown by measurement.

By request, Mrs. Laverne Bassett spoke on the impracticability of teaching physiology to pupils of the ninth grade, on account of their immaturity and the consequent trouble they had in understanding the subject or the text. That she had done it, to some extent, at least, by the laboratory methods, even on benches. Miss Pettee, of the Eastern High School, spoke also in favor of the laboratory method.

Mr. S. O. Mast, of Hope College, Holland, Mich., reported a year's experience in introducing laboratory work in physiology. He used Peabody's Laboratory Exercises, and found it an admirable book for the purpose. The course was entirely successful, and can be repeated for 25c per pupil if they pay for the material used. He emphasized the fact that the text-book may not be neglected, but should be used fully half the time. In answer to a question from the chairman, he said he used the book after observation and experimental work.

Dr. Barrows was asked to give his opinion on the relation in time and value between zoölogy and physiology. He said that much physiology can be taught in a course in zoölogy, but from the standpoint of zoölogy, the course in physiology should come first.

Reported by L. MURBACH.

Correspondence.

Editor SCHOOL SCIENCE.

DEAR SIR: In the April number I discussed the demand for science teachers. It may be of interest to compare the tabulation for this year with that of last. It will be seen that science still holds its place at the head. In nearly every case but one or, at most, two lines of work were specified. In the classification given below each request appears under such subject included in it.

Science, general, 16; physics and chemistry, 5; biology, 4; chemistry, 1; science with English, 2; with mathematics, 1; with Latin, 1; with history, 1. Total, 31.

English only, 9; English with Latin, 9; with history, 3; with German, 2; with science, 2; with art, 1. Total 26.

Latin only, 4; Latin with English, 9; with German, 5; with mathematics, 4; with science, 1; with Greek, 1. Total, 24.

German only, 2; German with Latin, 5; with French, 3; with English, 2; with commercial work, 1. Total, 13.

Mathematics only, 3; mathematics with Latin, 4; with science, 1. Total, 8.

French with German, 3; with commercial work, 1. Total, 4.

History only, 1; history with art, 1; with English, 1. Total, 3.

Art only, 1; art with history and English, 1. Total, 2.

Drawing and surveying, 1; commercial work, 3.

Athletics with other subjects (mostly science), 6.

Music (the ability to sing and to lead the opening exercises, at least,) was required in five cases and mentioned in others.

Stratton D. Brooks.
High School Visitor and Assistant Professor of Education, University of Illinois.

Editor SCHOOL SCIENCE.

DEAR SIR: A statement of fact in President Harvey's address, as reported in the last number of SCHOOL SCIENCE, strikes me as so remarkable that I feel impelled to ask for more light. That the "relative accuracy" of two classes in the physical laboratory should bear to each other the ratio of "seven to three," is, to me, an absurd statement, to which I can attach no definite meaning. Perhaps a fuller knowledge of the circumstances and data would make it plain and reasonable, but it is far from so at present.

Nor do I see the connection between the want of "accuracy" in his high-school graduates and the assumed cause in the lack of professional training of their instructors. It strikes me that a "physicist" would certainly teach "accuracy," whatever else he might fail to do. But possibly I misunderstood President Harvey's meaning. I certainly agree with him fully concerning the desirability of a better insight into the philosophy of education by science instructors.

Sincerely,

Chicago, Sept. 26, 1901.

A. W. AUGUR.
Lake View High School.

[In reply to the above letter permit me to say that I fully expected some one to express astonishment at the statement concerning the accuracy of the two classes referred to, and am quite prepared to state the facts in the case. The classes were found in the Wisconsin State Normal School at Superior. Each year for three successive years the high-school graduates were taught in physics in one class and those who were not high-school graduates constituted another class. All of the

high-school graduates had studied physics previously, otherwise they were not considered as high-school graduates for purposes of this division. There were approximately equal numbers in both classes each year, about thirty in each class.

The two classes did identical work on the same day. They used the same room, same apparatus, same teacher, same laboratory guides. The work was a series of exercises drawn from the Hall and Bergen Physics. The exercises included the determination of the law of elasticity in wires; laws of bending in rods, three exercises; laws of torsion, three exercises; the coefficient of linear expansion by heat, two exercises; the latent heat of melting; latent heat of boiling; specific heat of a solid; the laws of a pendulum, and the laws of falling bodies.

In making these determinations, the students did individual work. Each student worked alone unless the exercise was of such a nature that the co-operation of two or three was necessary to perform the exercise. They tabulated the results, and each one sought to determine for himself the law. In the final class discussion of the exercise, the tabulated results of all the pupils in each class were averaged and the average result in each class was made the basis of the discussion of the problem. It is the average result of the work of each class expressed in figures for every exercise that I referred to in my statement concerning the accuracy of the two classes. In seven cases out of every ten the average result of all the pupils in the class of high-school graduates differed more widely from the correct amount than did the average result of all the pupils in the class who were not high-school graduates. For example, in the determination of the distance that a freely falling body will travel in the first second of its descent, my last class of high-school graduates obtained a result differing from the distance stated in the text books by about 10 per cent; the class who had never studied physics missed it only by 3 per cent. The preceding year, the class of high-school graduates erred in the same exercise about 11 per cent. The other class about 6 per cent. That is, the average result of all the pupils in each class differed from the accepted amount by the per cent stated.

The difference in accuracy was so pronounced and so unexpected that it attracted my attention in my first year's classes very soon. Thereafter I kept a record of the results of each class, and 7 to 3, or seven out of ten, is a conservative estimate.

It was a case peculiarly favorable for comparison. The exercises upon the bending of rods, twisting of rods, and the stretching of wires were as unfamiliar to the one class as to the other. The class of high-school graduates were of course more or less familiar with what the result should be in the exercises concerning the laws of the pendulum, the laws of falling bodies, and the laws of heat. This seemed to have no effect upon the relative accuracy of the laboratory determinations.

Concerning the previous study of physics by the high-school graduates

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Les déléqués de la *Conférence des poids et mesures*, réunie à Paris en 1895. Phot. Eug. Pirou

The Delegates of the *Conference of Weights and Measures.* (By kind permission of Eug. Pirou.)

Supplement to SCHOOL SCIENCE, November, 1901.

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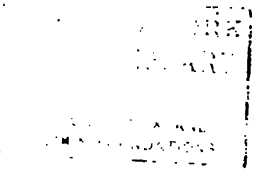

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School Science

VOL. I] NOVEMBER, 1901. [No. 6

THE LABORATORY AS A MEANS OF CULTURE.

BY W. L. POTEAT.

Professor of Biology, Wake Forest (N. C.) College.

Two agencies more than any others have contributed to the progress of science in the present century,—the organization of scientific societies and the equipment of scientific laboratories. The first served at once as a stimulus to ambition and industry and as a check upon hasty observation and unsupported theorizing. But valuable as this indirect agency has been, the laboratory, by its direct contributions to the increase of natural knowledge, has been even more powerful.

The essential feature of the laboratory method of instruction is that it brings the student into direct contact with nature. He does not study about nature; he studies nature. A book he values as a guide and help, but no matter with what authority it speaks, no matter how full and adequate the treatment, it is not allowed to come between him and his actual dealing with nature itself. The same is true of the teacher. His function is to stimulate, to make suggestions, to lead the way; and when he begins to retail to the learner what the learner can discover for himself, he in so far becomes rather a hindrance to scientific culture and subtracts from the total training which the laboratory would otherwise have given.

Indeed, there is no other way to become acquainted with the facts and laws of nature. The student who has not seen and handled acids and bases and salts does not know chemistry, no matter how full his text-book or lecture-notes. One who has merely read a book on botany is invariably confused and hesitating when he stands in the midst of plants. I once met at the seashore a lady who seemed to be familiar with zoölogy. I happened to have in my hand specimens of the common ascidian. She did

not recognize it. "Oh!" she exclaimed, "is that the ascidian? I have been reading so much about it and its bearing on the evolution theory."

But for the purposes of a liberal education the training which is incidental to the acquisition of the knowledge of nature is more important than that knowledge considered in itself. Now, what are the characteristics of the training given by laboratory courses? In the first place, the critical faculty is directly stimulated, and the observing powers are, of course, in constant exercise. The student acquires an intelligent respect for nature and for what is natural as opposed to what is merely formal and artificial. A wholesome self-reliance is cultivated. I have observed remarkable development in this respect in a single five months course. He learns to trust his own powers and grows strong in the assurance of first-hand knowledge. He tests and observes for himself, and receives nothing upon mere authority. No other exercise so develops the freedom and confidence of independent thinking. To these add manual skill and a certain equipoise and stability imparted to the whole round of mental accomplishments, and it will be seen that the laboratory as an instrument of culture is indispensable.

PHYSICS IN SECONDARY SCHOOLS.

BY CARL I. INGERSON.

Instructor in Physics, Normal and High School, St. Louis, Mo.

The proper place of physics in a course of study is predetermined by those characteristics which differentiate between it and other sciences. Were it not possible to fundamentally distinguish physics from the sciences generally, to draw a line of clear demarcation between natural philosophy and the other natural sciences, the prosecution of this branch of knowledge might be assigned indifferently to any period of the course, with equal promise of abundant achievements. But physics may be discriminated easily among the sciences, and he who fails to do so must either

*This paper was read in the Round Table Conference in Physics of the National Educational Association, Detroit, July 11, 1901.

accept the partial successes of his pupils, or else thank luck for results better than those which his lack of discernment entitled him to expect. Natural philosophy, the older designation of this science, is both apposite and illuminating. It implies philosophizing,—that is, reasoning like a lover of wisdom,—upon obvious phenomena in nature. Biology exercises the perceptive rather than the reflective faculties. It makes heavier demands upon memory than upon judgment. Chemist is alchemist, less its initial syllable; and chemistry, in rationalizing the mysteries of alchemy, has neither abrogated the imagination, nor circumscribed the range of its manifestations.

Nature study in the grammar schools could never rise to the dignity of a study of physics, even though natural phenomena engage the entire time and attention of the pupils. The necessary philosophic quality of mind is, to this class of learners, but a latent possession. That a child at nine years of age is a wholly different intellectual entity from the same child at twelve and sixteen is too patent to require demonstration; and I only state, categorically, that which you already know when I say that, at the earlier year in his life, perception and memory characterize his mental mode; a few years later imagination gives completion to the activities of his mind; while the reasoning, reflecting aspect of the intellect does not attain distinctiveness before the sixteenth year. The Jews had developed sound pedagogic practices more than twenty centuries ago. They recognized the processional incipiencies of the cardinal mental endowments, and suited the pupil's tasks to the order of his psychic evolution. Thus, the first ten years of his life were devoted to the simple memorizing of their sacred writings; and not until they had passed their tenth birthdays were Jewish youths permitted to listen to the Rabbis and to question them concerning the Scriptures. Furthermore, in the adaptation of study to acquired capacity, it is said that the difficult book of the prophecies of Ezekiel was withheld from the Rabbis until they had attained the mature age of thirty years.

It is possible to propagate roses in January, and to produce ice in August; but nature refuses to coöperate. There are times and seasons in the intellectual as well as in the physical world.

Moreover, the student of physics ought to bring to his study

of the science not only potential but also certain kinetic mental energies. If the saying be true that "the calculus is the language in physics," it is equally true that algebra, geometry and trigonometry are the alphabet, and the two- and the three-syllabled words of the language. Or, to change the figure, mathematics is the machinery of thought, by which alone the most and the best truths of physics may be apprehended. Niagara without a wheel is not to be compared for usefulness as an efficient force to a spring brook supplied with a tiny "undershot." πR^2 ought to be more than a form, or formula, to the pupil who has to do with volumes, and the sine of the angle of incidence should be a sign reflecting some intelligible light.

Considering, therefore, the inexorable demands which the inherent nature of the science makes upon the thought processes of the pupils, the last years of the usual high-school course, in which their reason and judgment are in a state of natural, vigorous development, and in which also their mathematical attainments are as full as possible, surely present peculiar advantages for the study of the elements of physics.

Botany and physiology precisely answer the requirements of the memory stage. Chemistry, appealing to the imagination, and suffering nothing, directly, from a deficient knowledge of higher mathematics, is admirably adapted to the growth of the child during the second general division of his mental unfolding, while physics, a philosophy, comes logically and conclusively last in the science course of secondary schools.

But the advantage of proper place may be rendered nugatory by the employment of improper methods. If some of our recent text-books accurately reflect the preferences and practices of the rank and file of physics teachers, there exists today a lamentable lack of true perspective in imparting the science. The spirit of the modern exposition seems to have invaded our schools, and to have placed a premium upon "live exhibits," giving them precedence of symmetry and the logical and meritorious presentation of the subject. As an illustration in point: In seven books taken at random from a larger number prepared for high-school pupils in physics, the proportion of space in each volume devoted to magnetism and electricity ranges from twenty per cent to thirty

per cent, and the average of the seven is twenty-seven per cent, or more than one-fourth of the entire matter in the books. Surely no argument is needed to show that these texts were written without due regard for the just balancing of the subject. Indeed, the impression is of Herbartianism gone mad; principle sacrificed at the altar of interest. Doubtless electrical demonstrations quicken interest. But we need to have a care lest our class-rooms degenerate from places of education into halls of diversion and amusement. Matter and its properties, motion and its causes, characteristics and measurements, elasticity, heat, light, sound, are both jointly and severally themes of intrinsic disciplinary value. Furthermore, the unreasonable magnifying of one, or the unfair minifying of another division, is a process wholly repugnant to the very spirit of science.

I wish also to file an indictment against such schools as lose sight of proper proportion in the allotment of time to didactic and to laboratory work. A school program that provides four periods in the laboratory to one period for class-room discussion, demonstration and recitation, forces upon one the conviction that its author places novelty above utility. The high-school laboratory has its uses, and they are neither few nor unimportant. It also has its natural limitations, which may not be extended with impunity. Some of its over-zealous advocates would put it foremost as a means of teaching physics. But the conservative, saving element of the teaching force believes, and rightly, I think, that the recitation room should always precede the laboratory, and that the province of the latter is to confirm and make real the facts, laws and principles that have first been discussed in the former. It will be freely granted that a laboratory is the proper place for that research out of the fruits of which a science is built up and established; but the laboratory of a secondary school is a place of confirmation and not a place of discovery. As one, therefore, for whom the laboratory is as a mighty magnet in its attractive qualities, to whom experimentation is an enthusiastic delight, and in whom the abandonment, or undue restriction, of this branch of our work would awaken a sense of personal bereavement, I cannot refrain from expressing the conviction of impending danger that the high-school physics labora-

tory may lose its proper character as an admirable auxiliary, and, by arrogating too much, precipitate a revulsion of sentiment as unwarranted as is the present exaltation of its function by some of its injudicious friends.

Our manner of teaching physics will depend largely upon the answer which we give to the question, What should a pursuit of this study yield the pupil? I believe there is a more or less unconscious surrender by instructors to utilitarian tendencies. "What's the use?" is the almost hourly interrogation of the schoolroom. And more fully expressed the query would take this form: "What is there in this which you require of me today that will enable me to acquire money when I shall be through school and shall have engaged in business?" In these times, when so much is said about "practical" studies, teachers need to remember and pupils need to be reminded that practicality inheres in the person and not in the knowledge which he may possess.

Have you pondered the fact that our high-school graduates prefer the university to the college for their further education? This trend is so strong that it has been predicted by high authority that the days of the college, as an educational force in our land, are numbered. What does it signify? Is it not a phase of the commercialism so rampant everywhere? The traditions of the college commit it to breadth of knowledge,—to scholarship. The atmosphere of the university is congenial air to the specialist,—the expert. The imperious demand is for training rather than for education; some faculties dragged forth, and not all faculties led forth. The high school experiences the stress. Pupils are impatient. They deem a span of more than two years between the primary school and the university a waste of time. And do we not, as teachers, sometimes, in hours of retrospection, experience a twinge of regret that we have, in unguarded moments, allowed ourselves to become accomplices in this crime of commercialism against the intellectual well-being of our pupils?

Not technical training, with a view to future money getting, but a strong, broad, symmetrical mentality should be the ideal towards which all high school teaching tends. Facts, principles, laws, methods of observation, methods of thought,—these the pupils must acquire; but only as means to an end, and that end the development of balanced, orderly, effective mental power.

RECENT ADVANCES IN THE PHYSICS OF WATER.

BY GEORGE FLOWERS STRADLING, PH. D.

(*Concluded from page 248.*)

By Eötvös, Ramsay and Shields and others it has been found that for all normal liquids the temperature rate of change of a certain function of the surface tension. molecular weight and density of the liquid is the same and remains nearly constant almost to the critical temperature. At temperatures below 40° C. water falls in with this law, provided the density and molecular weight of trihydrol are used, instead of the numbers which hold for ordinary water. From 60° to 100° the constant which holds for other liquids is approached, if the density and molecular weight of dihydrol are used. Therefore up to 40° the surface layer of water consists of trihydrol alone. Beyond 40° the reduction of the surface tension permits dihydrol to form in greater and greater quantities as the temperature rises.

From another point of view it seems probable that the surface layer should differ in composition from the body of the water. Pressure changes trihydrol into dihydrol, and conversely the tension which exists at the surface should change dihydrol into trihydrol.

Sutherland says: "The solubility of substances in trihydrol may be different from that in water." In connection with this some recent experiments of Jan von Zawidski* are of interest. He found that foam from aqueous solutions of acetic and of hydrochloric acid containing saponin is slightly richer in the solute than the main body of the liquid, and that the same is true of saponin solution by itself to an extent which far exceeds errors of experiment.

The latent heat of fusion of ice is to be regarded as including the heat required to dissociate some trihydrol into dihydrol. This is true also of the specific heat of water. The latent heat of vaporization includes the heat of dissociation of dihydrol into hydrol. It is calculated that 189 small calories are needed to convert 1

* Zeitschr, f. phys. Chem. XXXV. 77.

gram of dihydrol into hydrol at 100° and 177 to change 1 gram of trihydrol into dihydrol at 0°.

The problem confronting Sutherland was this: Given a substance well known in the solid, the liquid and the gaseous states, whose behavior, especially as a liquid, is different from that of ordinary liquids in respect to a considerable number of properties, to determine what must be the relative quantities, rates of change and physical properties of two simple and normal substances by whose mixture the comportment of water shall be reproduced. Of necessity he makes his appeal in many cases to analogy, with ordinary substances, for it is one of the conditions of the problem that its solution shall be in terms of such substances. Hypothesis often confronts the reader where he could wish to find a firmer foundation, yet the longer he studies the methods employed, noting the wide acquaintance with molecular data and the skill with which they are combined, the stronger does the conviction grow that this memoir has at last shown how to explain quantitatively the anomalies of water.

G. Tamman† has found that in addition to ordinary ice, I, there are two other varieties, II and III. They differ from the common kind in these respects:

1. Their melting points are raised by the application of pressure, whereas the opposite is true of ice, I.

2. Their density is greater than that of water. This accounts for the effect of pressure on their melting point.

3. They are formed only under special conditions of pressure and temperature. Common ice is cooled below —22° C. and the pressure increased to at least 2400 kg. per sq. cm. Now if the temperature is further lowered until it is from —30° to 60, ice III forms; if it is lowered to —80°, ice II forms.

When ice I changes into II, the following volume diminution per gram occurs:

−73°	0.171 cc.
−55°	0.180 "
−34°	0.193 "

†Drude's Ann., V., 597 (1901).

The heat of transformation of common ice into ice II or III is positive or negative according to the temperature, and is zero at about —33° for ice II, and at about —43° for ice III. The lowest temperature at which he observed water and ice to exist together was —22.4°, the pressure being 2230 kg. per sq. cm. The following table is given of the temperatures at which ordinary ice is melted at the accompanying pressures:

Temp.,	0°.1	2.5	5	7.5	10	12.5	15	20	22.1
Pressure, Kg. per sq. cm.	1	336	615	890	1155	1410	1835	2042	2200

It appears that the lower the temperature the less is the additional pressure requisite to produce a further lowering of the melting point by 1°.

Thiesen, Scheel and Diesselhorst* publish the following densities of water, determined at the Reichsanstalt:

0°	0.9998676	25°	0.9970715
10°	0.9997270	30°	0.9956736
15°	0.9991263	35°	0.9940576
20°	0.9982299	40°	0.9922418

In view of the long time during which the properties of water have been known and measured it is remarkable to how great an extent they still furnish a fertile field of investigation.

*Zeitschr. f. Instrumentenkunde, xx., 345.

THE STUDY OF BOTANY THIRTY-SIX YEARS AGO WITH ASA GRAY.

By W. J. Beal.

Professor of Botany, Michigan Agricultural College.

It is hardly fair to compare the work of botanists and zoölogists who were active thirty-six years ago with those now in their prime. Although often stated in educational journals, it is rarely comprehended by students of today that a knowledge of these subjects has advanced more within the past fifteen to twenty years than in all former years combined.

As a resident graduate, I took my degree at Harvard in 1865. At that time there were only two persons in America earning all their living by teaching and other work in botany, and they were Asa Gray, of Harvard, and D. C. Eaton, of Yale. A considerable number of other universities and colleges gave a little botany in the course, but this was taught by persons each teaching several other subjects.

How much time was required of undergraduate students in the study of botany? At Harvard and at the University of Michigan it amounted to a grand total of six weeks of daily work on one study out of three or four pursued at the same time. I know of no college in the United States which required students to devote more than six weeks to botany, save one, and that was the Michigan Agricultural College, where very nearly a year of daily work was required. No undergraduate of the institutions named could elect any more botany than above mentioned excepting at Harvard, where three or four weeks of daily work might be spent in identifying plants with help from the teacher.

Dr. Gray assigned lessons in his larger text book and students were thoroughly questioned over the ground with an abundant supply of fresh specimens to illustrate each topic. No drawings were made on the blackboard. There were four sections of the sophomore class of about twenty-five each. The time for a lesson was one hour. Much stress was placed on morphology,—in comparing corresponding parts of different plants with each other.

I must modify my statement of the work in botany at Harvard

by saying that once during a period of six years, Dr. Gray gave a short course of illustrated lectures on geographical botany, a course not fully appreciated by most students for want of previous study. This course was elective. The botanical department of Harvard did not possess a single compound microscope, but had a costly one in its possession. The field of work at that time open to botany consisted chiefly in describing and naming and classifying dried specimens which were frequently incomplete. This is known as systematic botany, but at that time almost no account was made of the minute structure of the plant as seen with the aid of a compound microscope, nor was much attention paid to the various stages of development of the parts. The work was based on the gross anatomy of plants as seen by a hand lens. The modes of collecting and pressing herbarium specimens were crude when compared with that of our best collections of these times. The reader will note that the time of the botanist of 1865 was chiefly devoted to systematic botany, morphology and the geographical distribution of plants. These were three fields of work closely related.

Dr. Gray employed no clerk, but performed a great amount of "dead work" with his own hands. All letters were written by himself with pen and ink. He was often brief in his replies, but in many cases his letters were full of interesting points, anecdotes and plans of work to be done. His letters were social and confidential, as well as scientific. A girl mounted plants for the herbarium.

A very small number of resident graduates—one to three at a time—learned botany under the guidance of Dr. Gray. For plant anatomy we read *Mohl on the Vegetable Cell* translated; only this and nothing more, for little else was to be had that was valuable, and this work was laid on the shelf as imperfect and out of date years and years ago.

We read *Lindley's Vegetable Kingdom,* identified hundreds and hundreds of dried plants, when we couldn't get them fresh from the fields, botanic gardens or the woods. We tried our hands at original descriptions and made artificial keys. We noted all the points which characterized the families of plants. Very little time was spent on plants below the ferns and their allies.

Let us take one long step in time from 1865 to 1901, and note a few of the leading points concerning plants that are now demanding the attention of students. New worlds have been discovered and each is now well taught in many colleges. I mentioned three above. We have them still, with additions, and five at least have been added, viz.: Plant histology, plant physiology, ecology, bacteriology, parasitic fungi and saprophytic fungi. Through the rapid development of agricultural colleges and work in the United States Department of Agriculture, opportunity was offered to earn money by a knowledge of plants. The universities soon gave a greater opportunity to elect botany than ever before. Today I dare not attempt to name or enumerate the hundreds of persons in this country, all of whom get their living by work with plants. Progress in every line is most marked, as we might expect where so many well-trained enthusiasts are occupying so many different fields. Botany in any of its departemnts is a charming and valuable study for pleasure, information, discipline or culture.

The older botanists of today have been obliged to bestir themselves continually to keep abreast of the times. They consult each other by letter, in person, or meet in conventions. They visit a number of the best equipped laboratories of this country or of Europe and remain as students or remain long enough to secure many hints that will be of value in work with their own classes. Without this, they would soon be shelved, or teach the old botany with none of the new.

THE HIGH SCHOOL LIBRARY FOR CHEMISTRY.

J. BISHOP TINGLE, PH. D.

Professor of Chemistry, Illinois College, Jacksonville, Ill.

Most teachers will probably agree that the provision of a library for the Chemical Departments of secondary schools is almost as essential to their complete efficiency as, say, an adequate supply of test tubes and flasks; yet it undoubtedly happens that,

in too many schools, the library is either totally lacking or wholly insufficient. I desire to call attention to this need, and, if possible, strengthen any efforts to meet it, because experience has shown me that the possession of a library will be speedily attended by beneficial results, both to the teachers themselves and to their students.

For several years it has been my privilege to interview students, with some chemistry credits, coming from other institutions, and to the question, "What work have you done on the subject?" I have frequently been told, "Oh! I have done a *great deal* of chemistry. I have had *a year of it*"; or, "I have done the *whole* of chemistry; we studied it *two hours weekly during six months.*" The italics are the student's. Obviously an individual entertaining such quaint ideas must first have impressed on him certain of the more elementary truths of perspective, and be brought to a truer realization of the actual relationship of his ego to the cosmos. The operation is usually rather painful to the student, somewhat of a bore to the teacher, and involves an expenditure of time that might be better employed.

Again, it is frequently found that an inaccurate statement or definition is regarded as beyond question "because So-and-so says it," So-and-so being the author of the text-book in use. The ideal text-book remains to be written, few of the available ones are without error, all have some blemish, and it appears that the teachers' efforts to correct them often had the effect of impressing the inaccuracies on the mind of the student with special force. A well-selected library materially helps towards the elimination of both these troubles; its use broadens the student's outlook as to the extent of the subject, and enables him to collate various accounts of any part of it. This often has the further great advantage of enabling him to grasp some special point, as put by B, that he may have vainly struggled with in A's book. In addition it begets in him the habit of reference, which must be of considerable value in subsequent work, and reading somewhat away from the routine lines will open up new paths of interest and extend old ones.

The chief advantages to the teacher of a library are perhaps two: access to reliable books of reference, and means of keeping

abreast of new work, including not merely the results of research as usually understood, but also improvements in lecture and class experiments, novel equipment, etc. Should the teacher be compelled to purchase his own works of reference, a somewhat heavy and rather inequitable tax is imposed on salaries usually far from liberal.

As regards the second point, many teachers are from their location necessarily deprived of ready access to current technical periodicals and books, and even if the works are available, the large amount of time required merely to "skim" them is a serious matter, whilst the rapid advancement of knowledge and the resulting luxuriant development of novel terminology, renders it difficult for any but specialists in various branches of the science to recognize the relative importance of new work and assess it at its approximate value.

THE STUDY OF BACTERIA IN THE PUBLIC SCHOOLS.

BY JAMES E. PEABODY.

Instructor in Biology, Peter Cooper High School, N. Y.

The highest aims in "municipal housekeeping" can never be attained by Boards of Health or by Departments of Street Cleaning alone, however efficient these organizations may be. Unless these city departments are backed by a strong, intelligent public sentiment we shall experience nothing better than sporadic reform in the cleaning of our streets, in the construction of tenement houses, and in the general care for the public health. When conditions get sufficiently bad in a community, it is comparatively easy to arouse the voters and roll in a reform administration by big majorities. But alas! we soon tire of our attempts at public virtue, we reverse our votes at the next election, and sink back into easy toleration of filth and its resulting disease. One might indeed become pessimistic with reference to the future of our cities were it not true that democracy possesses a most powerful means of developing a public sentiment which may be at once intelligent and lasting. Gathered in our schools of today are the

boys and girls who will be the voters and the home-makers of tomorrow. Hence to the teacher, especially in the public schools, is given the opportunity to exert a telling influence in developing the better city of the future.

The discoveries in bacteriology within a few years have made new sciences of surgery, medicine and sanitation. Epidemics of typhoid fever have ceased to be regarded as "a dispensation of an all-wise Providence," for we have come to know that the presence of this disease usually means a contaminated water supply or imperfect sewerage. Scientific men have learned, too, how to check the ravages of yellow fever and cholera, and even consumption is found to be a preventable disease. To make these discoveries of practical use, however, this knowledge must be possessed by a large majority of the citizens in a community, and the most effective means of attaining this end is by educating the pupils in our public schools. With this object in view, in the Peter Cooper High School, New York City, we devote considerable time in the course in biology to the study of bacteria, yeast, and moulds.

In this study, it is necessary at the very first to impress the pupil with some idea of the omnipresence of these micro-organisms in everyday life; and for this purpose an experiment performed by the boy or the girl is always more telling than a talk by the teacher or a dozen pages of description. We begin with the study of a hay infusion. The work is done by each pupil at home, and the report presented at the next recitation. The following account is selected from the one hundred and fifty papers received from the first year pupils:

Straw Infusion. I procured about a handful of straw at a livery stable and put it in a Mason jar three-quarters full of water, and put it in a warm place where the temperature was on an average of 75°, on Thursday, March 22. Its color was tan and the mixture smelt like musty straw.

The 23d, temperature 73°, mixture getting darker in color, and smell becoming more noticeable. Saturday, temperature 74°. A thin scum is forming and small things are coming up from the bottom and straw. The smell is getting very strong.

Sunday, temperature 74°, scum becoming thicker and bubbles appearing in it.

Discussion and microscopical examination in the class room

brought out the fact that the scum was composed of countless bacteria and other micro-organisms which had grown from the germs on the dried hay. The inference was drawn from the experiment that bacteria grow rapidly in a warm temperature, when water and organic matter are present, and that decay is one of the results of their activity.

The cultivation of bacteria in the laboratory was the topic next considered. Nutrient gelatin, the most useful medium in which to grow all kinds of bacteria, may be readily prepared in the laboratory or in the home kitchen. The ingredients necessary are the following: one pound of lean beef chopped fine (or better run through a meat cutter); 60 grams (2 oz.) of the best French gelatin; 6 grams (1-5 oz.) of peptone, which can be bought for 10 cents at any drug store; a teaspoonful of salt, and a little baking soda. Put the beef in a porcelain or agate dish, add a pint of cold water, and allow the mixture to boil slowly for a half hour. Strain the broth through muslin and then allow the liquid to run through filter paper. Pour in enough water to make the quantity of broth equal to about a pint and a half.* The gelatin, cut into small pieces, is then added to the broth, together with the peptone and salt. The mixture should be heated sufficiently to cause the gelatin to dissolve, but should not be allowed to boil. Just enough cooking soda is added to cause red litmus paper dipped in the mixture to turn blue, that is, the liquid should be faintly alkaline. Filtering the hot gelatin sometimes involves more or less difficulty. The process can be easily carried on, however, with a steam cooker. A glass funnel should be put in the mouth of a Florence flask (used commonly in a chemical laboratory) and one or two layers of absorbent cotton placed within the funnel. If the gelatin, flask, and funnel are kept hot within the cooker the liquid will readily pass through the cotton. After filtering, close the mouth of the flask with a plug of absorbent cotton, and boil for a few moments. The flask may be set aside as stock gelatin until needed for use. (If the gelatin mixture is not clear, it should be filtered through the same cotton a second time.)

Some of the liquid gelatin was poured into clean Petri dishes,

* This broth may be prepared more easily from Liebig's beef extract. Four grams should be dissolved in a pint and a half (750 cc.) of water, and the solution filtered.

or test tubes plugged with cotton may be used. After the gelatin had solidified some of the dishes were opened to the air. Several days after this exposure the cultures were placed upon the desks of the pupils, and they were asked to make drawings of the bacteria colonies, and to answer certain questions stated in the Laboratory Manual.*

One of the boys, not satisfied with the amount of laboratory work given in school, prepared nutrient gelatin at home. He writes thus of his experiences:

I took about a half pound of lean beef and after cutting into pieces placed it in a pot and covered with water, then brought to a boil. I should also mention that I used a moderate fire so that the process occupied about twenty minutes. After obtaining my broth I added gelatin and brought again to a boil. Here I added some salt and carbonate of soda, after which I strained the broth through cotton into a sterilized bottle and corked.

I experienced such trouble in clearing the gelatin of colonies that I finally melted the gelatin and poured it into test tubes and in them brought it to a boil with the result of one tube burnt and five cleared. In three of the tubes Mr. Peabody inoculated pure cultures; one of the tubes has produced a very large red colony, the others have not grown.

This laboratory work on the growth of bacteria was followed by an experiment performed at home by the pupils. One of the girls gives the following report of her work:

The Study of Bacteria in Milk. I procured three bottles of about the same size. I then thoroughly cleansed each bottle before I used it. Two of the bottles had stoppers; the other had none. One of the bottles I half filled with good fresh milk, put the stopper on, and set it outside the window. I labeled this bottle "No. 1."

Into the second bottle I poured about the same amount of milk, and set it aside in a warm temperature of about 70°. I labeled it "No. 2."

The third bottle I cleaned in very hot water. I then boiled the same amount of milk that I put in each of the other bottles. I allowed it to boil for about three minutes. After the milk had cooled a little I poured it into the third bottle. I placed it beside bottle No. 2, and labeled it "Sterilized Milk."

At the end of fifteen hours I examined each of the bottles. I

*Laboratory Exercises in Anatomy and Physiology.—Henry Holt & Co., 29 W. 23d St., N. Y. City.

noticed that No. 1 had very little smell at all. No. 2 had a sour like smell. It smelled as if the milk were turning. No. 3 had hardly any smell at all. If there was any smell at all, it was a sweet one. I now boiled the milk in No. 3 again. I first thoroughly cleansed the bottle and cork before I put the milk in. I then placed it beside No. 2, and put No. 1 again outside the window.

At the end of twenty-four hours I again examined my bottles. I found that No. 1 had not any smell at all. No. 2 had a very decidedly sour smell, and No. 3 had a sweet smell.

The changes in the milk are due to the growth of the bacteria from the air, or on the bottles, or the stoppers. As far as my experiment has worked I do not think a cold temperature kills the bacteria, but I think it numbs them. I think a boiling temperature kills the bacteria, and I think a moderate temperature increases the growth of the bacteria.

Successful microscopical work was done with magnifying powers of about 500 diameters. Pure cultures of spherical-, rod-, and spiral-shaped bacteria growing in test tubes of gelatin were supplied us by Dr. T. Mitchell Prudden of the College of Physicians and Surgeons, to whom I am much indebted for help in this bacteriological work. Microscopical slides are easily prepared thus: Hold upside down the test tube in which bacteria are growing, and carefully remove the cotton from the mouth. Touch one of the colonies of bacteria with the point of a needle, and then rub the needle point on a clean glass slide; add a drop of water to the spot touched by the needle, cover with a cover-glass. Stains (Loeffler's methylen blue and Ziehl's carbol fuchsin) bring out more clearly the structure of the bacteria. Each of the thirty-five pupils in a division examined the stained bacteria, and watched under another microscope the motion of the living forms. One pupil's written account of this study is here given:

Microscopic Study of Bacteria. 1. The bacteria which I saw under the microscope last Wednesday were of red and blue colors. This was caused by the coloring matter (stains).

2. They were of three different shapes, round, pencil-shaped, and corkscrew.

3. The bacteria which I saw to-day under the microscope are moving around.

4. There were also under the microscope egg-shaped animals which were moving around. (This slide was prepared from the hay infusion and contained infusoria.)

A little mathematical problem worked out by each student helped to make real the rapidity of multiplication among these micro-organisms. The pupils were told that a rod-shaped bacterium, when conditions are favorable, divides in about an hour to form two bacteria. The problem was stated something like this: Suppose we start with a single bacterium this morning at 10 o'clock; if conditions are favorable, how many cells could be seen at 11 o'clock? The answer was "two." Between 11 and 12 o'clock each of the two would divide to form two; hence at 12 o'clock it was evident that there would be four bacteria in place of the single cell at 10 o'clock. The pupils, continuing the calculation, found that if the process were to go on until 10 o'clock the next morning, the original bacterium would give rise to 16,776,216. The completion of this calculation for a second day's crop of bacteria was not attempted for obvious reasons.

Thus far the experiments and discussions had made real to the pupils the existence of countless millions of micro-organisms. They had learned something of the form, size, and motions of the individual bacteria; and they had become acquainted with some of the results of their activity in causing decay, in souring milk, and in producing colors.

Some of the conditions which tend to check the growth of bacteria were learned from the milk experiment performed at home. A laboratory demonstration developed this subject still further. One of the boys described the experiment thus:

Sterilization. Mr. Peabody took three test tubes and inoculated some of the bacteria from the hay infusion. The first test tube contained nourishment in a solid form (nutrient gelatin), and after the bacteria had been inoculated it was set aside. The second test tube was prepared the same way, but Mr. Peabody poured some corrosive sublimate over the surface of the gelatin. The third test tube was prepared in the same way as the first, but was put in the (steam) sterilizer for five minutes, and then set aside.

At the end of five days we examined the tubes and found that the two tubes, one sterilized by heat and the other by poison, were perfectly clean, while the other had a large colony growing. From this I infer that corrosive sublimate and the heat killed the bacteria.

We are fortunate in possessing a hundred copies of "The Story

of Bacteria"* and a like number of "Dust and its Dangers"* by Dr. T. M. Prudden. These books were loaned to the 192 pupils who were studying the subject, and about one-fourth of the chapters were assigned for text-book lessons. One may judge of the interest in this study by the following figures: When the books were returned it was found that 103 pupils had read the whole book; that the books had been read by 197 parents or friends of the pupils; and that various topics in bacteriology had been discussed in over half of the homes.

(*To be continued.*)

GAS GENERATOR.

BY GEORGE A. COWEN.

Instructor in Chemistry, West Roxbury High School, Jamaica Plain, Mass.

A convenient and useful generator can be made as follows: Two bottles of equal size are fitted with tubes and stoppers as shown in Fig. 1. Bottle A contains the solid,—zinc, marble, or

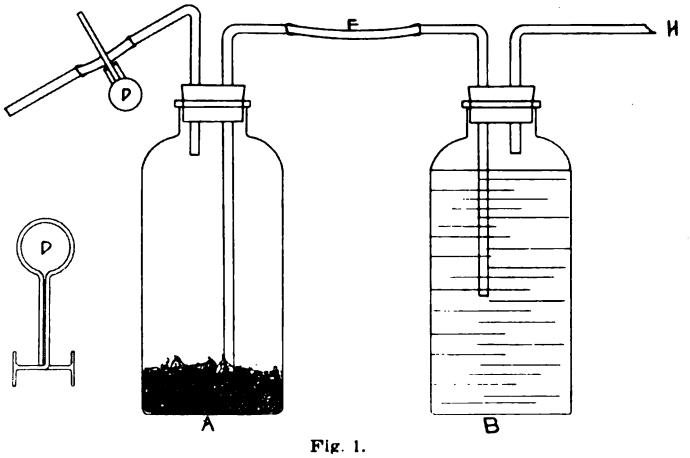


Fig. 1.

*Published by G. P. Putnam's Sons, W. 23d St., N. Y. City.

sulphide of iron; B contains the dilute acid. To start the reaction, open stop cock D and blow gently through H. The acid siphons over through F until its end is exposed. It is necessary to have this tube short, that the siphon may empty and cause a slight back pressure. When considerable pressure is required a stopper must be placed on H. When the stop cock is closed, the liquid returns to B and action ceases.

It will be noticed that the upper and better part of the acid is always used.

While gas is being delivered, B can be disconnected at F and the spent acid thrown away.

A generator of this form can be made for 25 cents. The bottles can be put in a block for convenience in handling.

A DISCUSSION OF NEWTON'S THIRD LAW OF MOTION.

By E. E. Burns.

Instructor in Physics and Chemistry, DeKalb (Ill.) High School.

The thoughtful pupil, who is studying the laws of motion for the first time, is sure to find difficulty in reconciling Newton's third law with the principle of balanced forces. The meaning of this law is that every force is accompanied by an equal force in the opposite direction. Before reaching this point, the pupil has been taught that, if two equal forces act in opposite directions upon the same mass, no motion results. If these two statements are the whole truth, motion is an impossibility.

A simple illustration makes the matter clear. I have used the following in my class room and I have good reason to believe that the result has been a clear conception by a majority of my pupils of the meanings of these two laws and the relations existing between them: I hold in my hand a spring balance from which is suspended a mass of, say, five pounds. The force due to gravitation is five pounds and is acting upon the mass in a downward direction. The hand is exerting an equal force in an upward direction and there is no motion. These points and

those that follow are, of course, brought out by questioning. To move the mass upward, the upward acting force must be increased. I do this and, for an instant, the index of the balance indicates eight pounds. The total force exerted by the hand upon the mass at the instant of setting it in motion is eight pounds. That the mass is affected by an equal force in a downward direction, we know, since it stretched the spring as much as an eight-pound weight would do. The added downward force of three pounds is due to the inertia of the mass (and this makes the meaning of inertia more clear). We have, then, two equal forces acting in opposite directions upon the same mass and the mass is set in motion. This is true because one of those equal forces consists in part of the force due to inertia. We must, therefore, recognize a force of inertia and we may include Newton's third law and the principle of balanced forces in one comprehensive statement thus: Every force is accompanied by an equal opposing force. The effect of such equal opposing forces is rest, except one of the forces consist in whole or in part of the force of inertia, in which case the effect is motion.

EXPERIMENTS WITH THE SCHOOL ELECTRICAL MACHINE.

By Oliver P. Watts.

Instructor in Physics, Waltham (Mass.) High School.

For two years past, whenever time has permitted, I have been conducting a series of experiments which are of the greatest interest to me, and which I believe will prove of equal interest to most science teachers. As the necessary apparatus ought to be, and probably is, to be found in every high school, I call the attention of high school teachers to them. The experiments are a study of the forms of high potential electricity as recorded by its direct action on the photographic plate.

The first success in producing a visible record of electrical forms seems to have been achieved by Lichtenberg, in the last quarter of the eighteenth century, by dusting sulphur, red lead,

etc., upon a non-conducting plate which had been touched with the knob of a charged Leyden jar. The first electrical record upon a photographic plate was undoubtedly a photograph of lightning. Who first tried the direct action of electricity upon the photographic plate, I do not know, but it had been done in England at least as early as 1892. My first knowledge of it came from an exhibit of such pictures in connection with a powerful induction coil, at the Mechanics' Fair in Boston, in the fall of 1898. In answer to my inquiries of the man in charge of the exhibit, I could only learn that the pictures were made with the coil without using a camera. In January, 1899, I commenced experiments with the school static machine, though with small hope of success, as the longest spark that I could obtain was one and a half inches, instead of the sixteen to twenty-two inch spark of the coils exhibited. I worked at night by a ruby lantern, holding the film side of the photographic plate against the poles of the electric machine, and developing the plates as usual after exposure. I quickly discovered that the film was a somewhat better conductor than air, and so sparks could be obtained across the plate more than twice the maximum sparking distance in air.

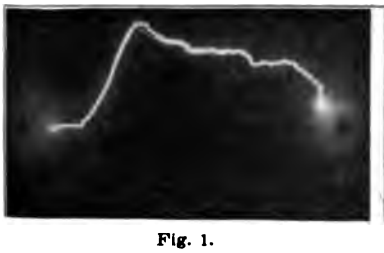


Fig. 1.

Fig. 2.

Fig. 1 (size of original 3¼x4¼ inches) shows one of the earliest, if not the first picture that I made. Surrounding the two poles are faint streamers, which even here are seen to be unlike in form. I soon found that by the inductive action of a strip of tinfoil on the glass side of the plate, the length of spark was considerably increased, as was also the spread and intensity of the action outside the spark itself, as seen in Fig. 2. Fig. 3 shows

the blue, scarcely luminous, streaming discharge obtained when the Leyden jars of the machine are disconnected. The general tendency of the radial streamers from the positive pole is to avoid each other, and to branch indefinitely. On the side toward the negative pole this tendency is disturbed, and a discharge takes place, not only from those streamers which start directly towards the negative pole, but from others which curve around, when they reach a point somewhat remote from the positive pole, and join themselves to streamers going to the negative pole more directly than themselves. At the junction there is a spot of in-

Fig. 3.

Fig. 4.

creased action on the plate. The whole figure shows the superior spreading and reaching out of the positive electricity. Fig. 4, which might well represent a dandelion or some similar flower gone to seed, was made by holding a plate perpendicularly between the poles, and is a record of positive electricity.

Fig. 5 (original 8x10 inches) shows well the branching dendritic form characteristic of positive electricity, and the feather-like character of the negative. This is one of a dozen pictures made at Harvard University, through the kindness of Professor Hall. The machine with which it was made gives a five-inch spark. To form these perfect figures, it is necessary to set each kind of electricity free from the attraction of that at the opposite pole, which otherwise would cause a spark discharge to take place. This is done by placing a sheet of tinfoil, or any other conductor, beneath the plate, when by induction the opposite electricity is developed everywhere beneath the branches on the film side, and because of its nearness, "binds" the charge on the film. Under these conditions, positive and

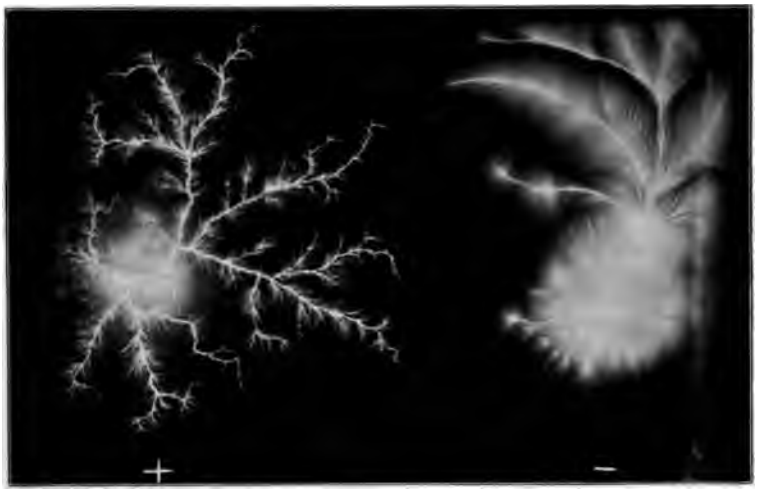
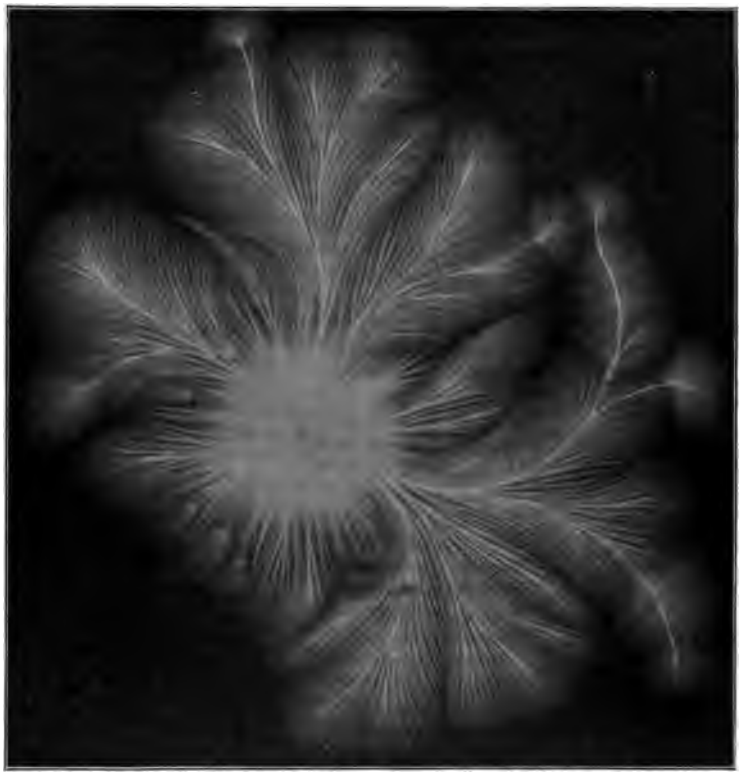


Fig. 5.

negative may approach within one-half inch of each other without any sparks passing, and so they may develop freely over a great extent of surface, each according to the force or forces within itself. Such a plate is heavily charged with electricity and is, in principle, a Leyden jar, except that because the film is a poor conductor, by touching the two surfaces, the discharge is only in the vicinity of the part touched on the film side.

These are a few out of many interesting forms. While I do not feel that I have discovered as yet any facts about electricity which are of great scientific importance, yet I have learned many things which to me are very interesting, and I am sure that there is more to be learned by further experiment. If a plate be charged by holding it between the poles of the machine, taking care that a spark does not pass over the edge of the plate, in the finished picture broad bands of light will be seen following in a general way the course of the main branches on the film side of the plate, though not coinciding exactly. These are sparks which went out from the opposite pole to charge the plate on the glass side. I am convinced, that for any electrical disturbance on one surface of a plate, there is always one of an opposite



A Beautiful Negative Charge

nature on the other side. This is only a visible illustration of the old story that the two "kinds" of electricity are always associated in any electrical disturbance, never one alone. Other observations cannot be even mentioned in this article for lack of space. Many questions arise: Is this action on the photographic plate due solely to the light of the electric spark, so that these pictures may properly be called photographs, or is it an effect produced by the electric current? Is lightning only similar sparks on a grander scale, having such minute tributaries and veinings accompanying all its ramifications, or does the camera reveal all that there is to the lightning flash? I find seeming corroborations of each view. The whole subject is a most fascinating one to a

person who has any fondness for experiment, and the beauty of the results will well repay the time and expense of securing them. The teacher of physics will find these pictures a help in showing pupils by visible, indisputable evidence, that the terms positive and negative stand for a real difference in electrical conditions, and are not mere names coined to bolster up a doubtful theory.

Instead of a static machine, a coil of similar power may be used. A one and a half inch spark will produce figures covering a four by five plate; a two-inch spark will cover a five by seven, and a five-inch spark will cover an eight by ten plate very well. By wrapping the plates in black paper, a little light may be admitted to the operating room, though it should be remembered that the spark pierces the paper. In this case, quite an alteration is produced in the form of the negative figures, and they somewhat resemble the positive in form. (Any information on the literature of the subject, or photographic prints of lightning resembling these figures will be appreciated by the writer.)

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

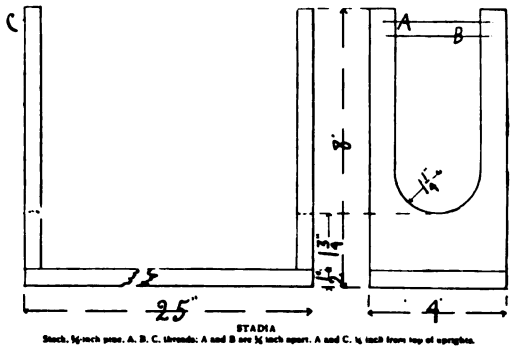
(*Continued from page 263.*)

EXPERIMENT VIII.

To map with a plane table and home-made stadia the form and outline of a field, or pond, and locate any permanent objects within it.

Construction of apparatus.

From surfaced inch-stuff, cut two pieces according to the dimensions given in the drawing. To one attach two strips of tin or brass, or card-board, as shown at C, and to the other fix two



STADIA

Fig. 11.

parallel black threads ¼ inch apart as shown at A and B. From the same stuff cut, square, and surface a board 25 inches long and nail the former two pieces to the latter.

By looking through the back slit between the strips at C, first toward the upper thread, A, and then at the lower one, lines of sight may be directed toward a remote object at such an angle with each other that the distance of the object sighted will be 100 times as great as the length of the part of the object included between these lines of sight. Measuring the space, therefore, the distance of the object becomes at once known, and *vice versa.*

Place the plane table (Fig. 7) over some commanding point on or near the tract to be plotted, and, if the tract is level, bring the board into a horizontal position with the aid of a spirit level, such as is suggested under Experiment V (b). In other cases tip the board by shifting the tripod legs until it is roughly parallel to the surface of the tract to be mapped. With thumb-tacks attach a piece of paper to the board, and, sticking a pin at some convenient point, sight the alidade, held against the pin, to flagpoles placed at salient points (corners, or sharp turns) drawing lines with a sharp pencil along the edge of the alidade in its various positions.

Removing the alidade and placing the stadia upon the table, with its edge parallel to the successive lines, an assistant will note and record the length of the space intercepted on the

flagpole at each point about the perimeter, and at any objects on the tract to be plotted, between the two lines of sight, one passing from the eye-hole (C) over thread A, and the other from C over thread B. If the instrument has been constructed in accordance with the specified dimensions, the distances from the table to the various poles will be 100 times the intercepted spaces on the poles. Why?

These distances may now be laid off from the pin on the lines drawn with the alidade to any desired scale, and a line drawn through the perimetral points will give the outline and form desired. Objects will be located in their proper relative places by plotting the corresponding distances on the lines from the pin toward the respective objects, the same scale being used.

PROBLEM: Map and locate from any convenient point the form and objects of your playground, or other tract of ground being studied.

EXPERIMENT IX.

To find the diameter (roughly) of the moon or sun.

(a.) Holding a graduated lead pencil at arm's length, place the thumb so that when the end of the pencil is in line with one crescent tip the thumb will be in line with the other tip. Note the distance from the thumb to the end of the lead pencil. Assuming the distance to the moon to be 239,000 miles, what is the moon's diameter?

[REMARK: The value of this method of executing the experiment is in showing on what the solution of the problem of finding the lunar diameter depends.]

(b.) The experiment may be performed more accurately with a stick placed at some twenty feet from the eye, the distance between the points on the stick where the lines of sight to the two crescent tips pass it being measured.

(c.) A movable sight carried along a scale fixed perpendicularly to a stick or rod some twenty feet long will give a still more accurate solution.

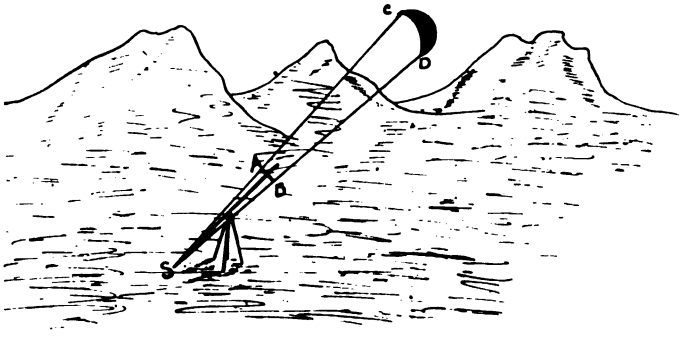


Fig. 12.

(d.) These measured values may be checked by the aid of Ephemeris' data, or with Sextant measures. (A cheap wooden sextant can be bought of the Chicago Laboratory Supply and Scale Company).

(e.) These same experiments may be carried out for the sun by shielding the eyes with a pair of colored spectacles, or with the aid of smoked glass. When the moon is very bright, slightly shaded spectacles will make better settings on the lunar limb possible. See also Fig. 13 for a convenient form of apparatus for this experiment.

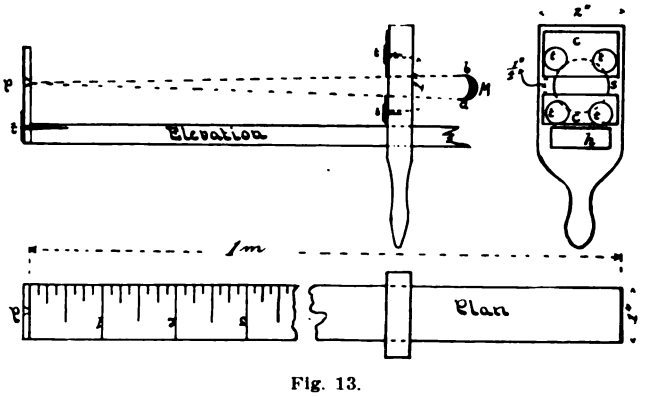


Fig. 13.

Experiment X.

To determine the form of the moon's orbit.

Using an apparatus similar to the one figured here, a good idea of the principles involved in determining the form of the moon's orbit may be obtained.

The apparatus consists of a yard or meter stick, at one end of which a thin strip of wood, or card-board, is pinned with a thumb-tack. This strip is perforated at P with a pin-hole through which the sights are to be taken. A paddle-shaped carriage, supplied with an oblong hole, h, of such form and size as to slide with gentle friction along the meter stick, is perforated with an inch-hole, the center of which is about as high above the upper surface of the meter stick as is the pin-hole. Across this hole two card-board strips are pinned, with thumb-tacks, with edges parallel and a quarter of an inch apart. The advantage of using the yard, or meter stick, is that a self-graduated measuring bar is thus secured. Indicated dimensions are intended only as suggestions.

The measures are taken by looking through p and tipping the apparatus until the line of the crescent tips of the moon stands perpendicularly across the slit, S, at the same time sliding the carriage back and forth along the bar until the tips of the crescent simultaneously just touch the respective edges of the slit. The distance from p to t is then read off, and is the observational datum furnished by the instrument.

Reduction and Interpretation of Observations.

Tie the ends of a cord some forty or more feet long, one to a stake stuck in the ground at a point as F1, and the other at F2, at a distance of some 25 feet from F1. Catching the cord at some intermediate point, say C, draw the cord aside until the ends CF1 and CF2 are equally taut and then stick a peg at C. In a similar way stick pegs at D, E,....A. Placing a globe of (say) one inch in diameter at A, and standing with the apparatus at F1, slide the paddle to and from the eye until the edges of the globe are tangent to the edges of the slit, S of Fig. 13. Read the distance to t, the setting of the paddle, and record it. Also measure the distance NF1, on the ground and record it in a

column beside the setting of the carriage. Move the globe to C. and record the two data for this point in the same way. Proceed similarly for some eight or ten points on the ground. By examining the two columns of data can you discover any law connecting them?

ANSWER: They are proportional.

Hence, if we should draw on a sheet of paper by aid of the apparatus of Figure 7 a number of lines from a given point, directed toward the points A, C, D, E,....A and then lay off on these lines the values of the readings furnished by the carriage settings, by drawing through the points on the paper thus located, a continuous curve, we should get a curve of the same shape as the continuous curve drawn through all the points on the ground. That is, we could infer from the curve on the paper *the form of the curve on the ground.* Note that this inference is based entirely on the readings of the instrument.

Laying off on a system of radiating lines, the carriage settings for the moon from day to day, or from week to week, we might then in this way infer the form of the moon's path from the curve we draw through the points located on the paper by the instrument settings, *if we could draw the radiating lines so as to make them include between them the proper angles.* These angles may be obtained with sufficient approximation for this purpose by taking the difference of the longitudes of the moon for the dates of observation from the *American Ephemeris.*

They may also be obtained observationally by the aid of the cross staff by measuring the angular distance of the moon from a star just ahead of, or behind, the moon, for two, or three, consecutive times and subtracting, or by triangulating with the cross-staff the distances from the two stars along the moon's path, locating the stars by their right ascensions and declinations on a globe, indicating with a pair of dividers by two intersecting arcs the positions of the moon for the dates and scaling off the number of degrees between the successive positions. See under cross-bar, Fig. 15, Experiment XII.

When the form of the moon's path has been thus drawn, if any one of these distances be obtained from the *American Ephemeris*, the scale of the drawing will become known, and the dis-

tances corresponding to all of the dates of observation are readily deducible.

Carry out the measures on the moon for intervals of two or three days throughout some entire month.

(To be continued.)

Metrology.*

THE CENTENARY OF THE METRIC SYSTEM.

BY JACQUES BOYER, in *Revue Encyclopedique Larousse.*

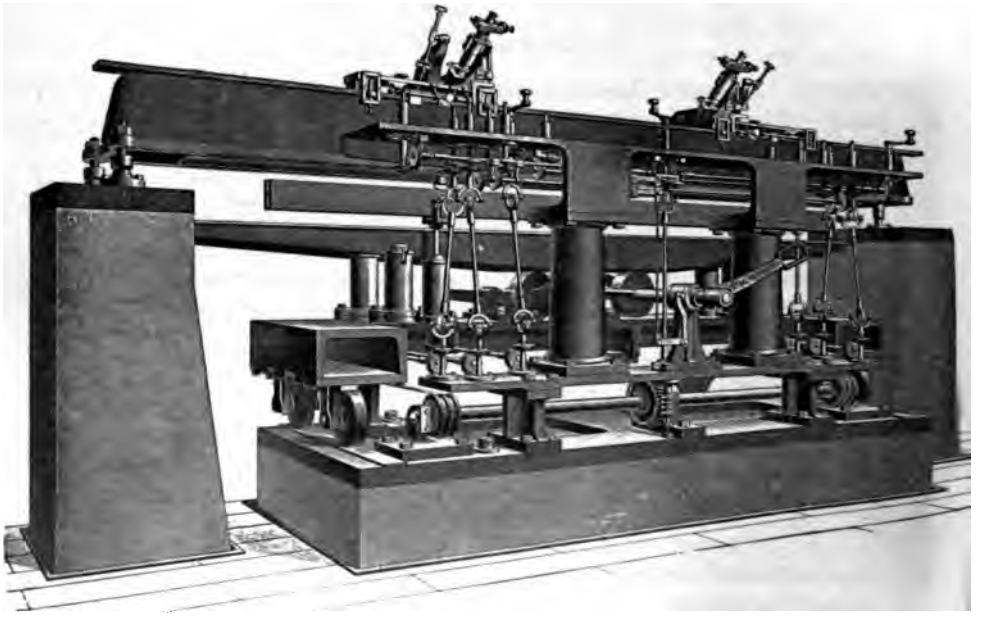
Translated by DR. WILLIAM H. SEAMAN.

(Concluded from page 212.)

These instruments differ slightly from each other according to particular work for which they are intended. The first, made by Brunner, is adapted for line measures, that is to say, scales in which the length is determined between two lines, one drawn on each end of the scale. The microscopes, solidly fastened to the heavy masonry, carry micrometers such as are commonly used on optical instruments, and furnished with spider threads moved by micrometer screws. These threads are made to coincide with the lines of the scale by turning the screws a certain number of divisions, and knowing the distance corresponding to each division of the screw head, it is easy to determine the distance between the lines on the scale. The body of the comparator is an enormous casting whose top is a kind of railway over which rolls a heavy carriage moved at will by gears controlled by a handle. On this carriage rests a double walled box of metal in which are placed the two scales to be compared. The mechanism allows the operator to move the whole box in any direction so as to bring each extremity in focus. In this way the lines on the ends of each are carefully compared, and besides the comparator is furnished with thermometers provided with magnifiers by which their movements are seen and all sudden variations of temperature are

*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

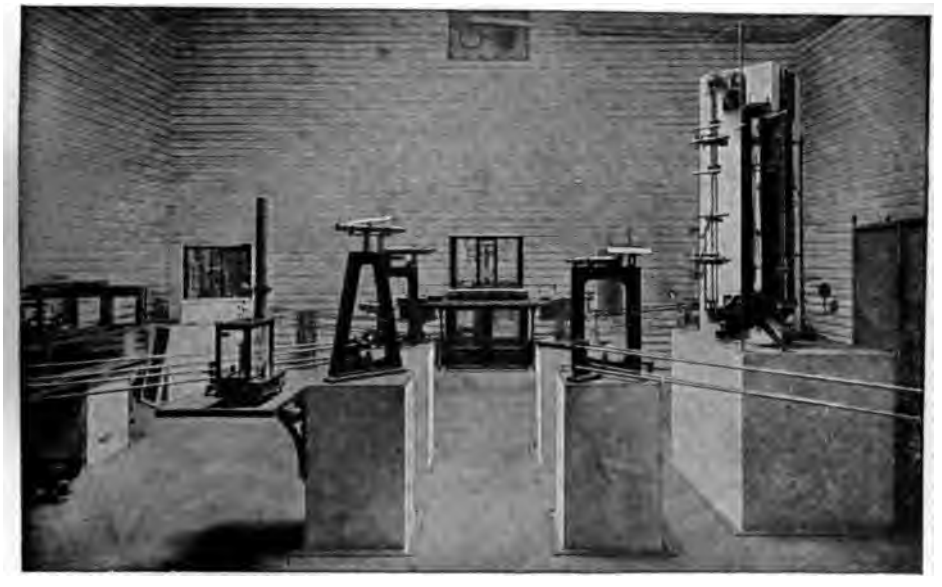
carefully avoided. The second comparator is for the purpose of studying the expansion of metric scales. It differs from the preceding in that the carriage has two boxes separated from each other, in each of which a scale may be placed and subjected to different temperatures. The standard one is kept at a fixed temperature, while the other is heated or cooled. Thus its contraction or expansion is measured by reference to the standard near it. We need not speak of the difficulty of maintaining a constant temperature, but we may say that the arrangements at Breteuil enable a liquid bath to be kept for hours at a temperature varying only by a few hundredths of a degree. These two instruments enable us to determine the relative length of two scales within a few microns, while with the third comparator, called the universal, lengths up to two meters may be examined. This instrument differs in several particulars from the others, its microscopes are not fixed, but are borne by two carriages that roll on a sort of bridge extending between two pillars of masonry. This bridge is a heavy casting that has steel ways on its upper side made perfectly horizontal, which guide the movement of the microscopes. When placed in the proper position these are fixed by a set screw. Underneath is a carriage for the measure to be examined, capable of motion in every



The Universal Comparator of the International Bureau of Weights and Measures.

direction on a horizontal plane. The instrument has a scale divided into centimeters, and was made by Starke and Kammerer of Vienna, and does great honor to that establishment. It is shown in our illustration without the mahogany box which encloses it. It has many uses, the comparison of end measures, the determination of dimensions other than those of the metric system, the determination of subdivisions of the meter, especially of the millimeter, which is so necessary to fix the degree of precision observers may expect from micrometric instruments employed in delicate experiments. The last instrument is the geodesic comparator, which is a combination of five comparators. As its name indicates, it serves for the study of the large rods, four meters in length, used in the measurement of base lines in geodesy. This work is very difficult. It is done by the help of electricity, but its construction is too specialized to render a description desirable here, and we pass to the other apparatus of the pavilion of Breteuil, viz., that intended for the examination of weights.

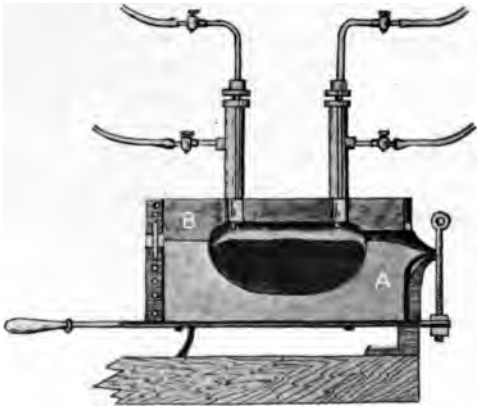
The weighings at the International Bureau are made with balances of great precision in a room especially designed for this purpose. Those which are used for the determination of the kilogram are so arranged that they may be manipulated at a distance. On the evening of the preceding day,



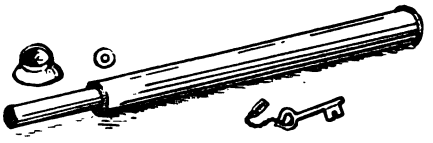
The Balance room of the International Bureau of Weights and Measures.

the observer places in the case of the balance to be used the weights that are to be employed, since he may not again come near it for fear of changes in temperature his presence would cause. Twenty-four hours after he performs the weighing at a distance of at least four meters by means of the long lever arms shown in our illustration. That is to say, the balance is provided with ingenious mechanism by which the weights may be placed, changed from one scale to another, the balance liberated, etc., etc., from a distance. The oscillations of the index are observed by a telescope fixed by metal to one of the pillars that support the various levers. A mirror is attached to the index of the balance which reflects a divided scale of which the image is seen by the observer to move in the glass when the balance oscillates. The extreme positions, or ends of the swing, are noted and the mean taken for the position of equilibrium. The delicacy of these instruments is such as to admit of detecting a difference of one-hundredth of a milligram between two kilograms. It would require too much space to speak of the other balances, or to describe the apparatus used to measure temperature, which measurement is very important in determining standards of length or of weight.

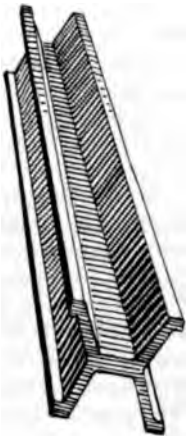
Having now described the principal instruments of the International Bureau, let us return to a history of the more important researches that have been executed since 1878, for the purpose of establishing a new international meter.



Oxyhydrogen furnace used for melting platinum. A, crucible. B, crucible cover. C, handle to raise the crucible and pour the melted platinum. R R, supply tubes for oxygen and hydrogen.



Case for one of the Prototype Copies of the Meter.



Form of the new Standard Meters.

The meter of the Archives is made of a flat bar of platinum, forged by Janetti from platinum sponge. The extremities are rounded, and the distance between the middle of the two end faces, measured at zero, defined the meter of 1799. This form has been abandoned by modern metrologists because they have recognized certain advantages possessed by strong lines drawn on the plane of the neutral axis of a bar. This plane contains the center of gravity of the bar, and its length is independent of the mode of suspension. The material is an alloy containing 90 per cent of platinum and 10 per cent of iridium. Many analyses were required before the proper mixture was obtained, and three years of labor were spent before the ingot was cast. As the metal cost 3,000 francs per kilogram, an X form was chosen for the sake of economy, and also because the maximum of rigidity was thus obtained with the minimum of weight.

The international prototype meter was obtained in the following manner: First, a provisional standard was made as near as possible the same length as the meter of the Archives. By many measurements it was proved to be six microns longer.

This work was done in 1881-2 by a commission composed of MM. Broch, Forster and Stas, members of the International Committee, and Dumas, Tresca and Cornu, of the French section. The latter then took charge of perfecting the standards, while the others attended solely to their verification. When the length of the provisional standard was determined, it was used to prepare forty prototypes. These various scales were compared among themselves and it was shown no one of them differed more than three microns from the meter of the Archives.

That which was the nearest in length was called the International Meter and was afterward denoted by a German capital M in all diplomatic and scientific documents. All the standards were then compared for the last time. Most of the work was done by M. Benoit, the director of the Bureau, and was concluded towards 1888. The following year the general conference of the meter again met at Paris, September 24-28, 1889, to give legal authority to these metric prototypes. The international standard was placed in a safe in a deep cellar having three locks whose keys are in the hands of three men, the director of the Bureau, the president of the International Committee, and the director general of the Archives of France. Lots were then drawn to see to which of the contracting nations particular prototypes should be assigned, and they, having been compared with the meter, will henceforth determine the unit of length for all the nations of the world.

When all these operations were finished, and the scales cleaned with hydrochloric acid, they were placed in envelopes designed by Dr. O. J. Broch. No precautions were spared to have them arrive safely at their destination. Semi-cylindrical boxes of beech wood were made, one fitting over the other, and provided with grooves lined with velvet in which the scales were laid. The whole was then put in a stout brass tube closed at one extremity and provided with a screw top at the other end which could be locked. When the various cases were properly packed each of them was transported to its final resting place in Russia, Japan, and across the Atlantic with almost royal honors. We will only mention the arrival of those sent to the United States. During the journey the delegates were responsible for the care of the cases and on their arrival were treated as persons of distinction, and directed to the White House. There the cases were unpacked in the presence of President Harrison and the principal *savants* of Washington, and a dance was improvised for the occasion. Similar methods were pursued with the kilogram. Messrs. Johnson, Mathey & Co. of London furnished the alloy for the meters, which was analyzed to be certain of its purity. After a series of weighings executed at the Normal School and the Observatory by Henry St. Claire Deville, the International Committee of Weights and Measures selected as the international prototype that one of three kilograms whose equation came nearest to that of the Archives, and inscribed it with a capital German K. This international kilogram was then taken to the International Bureau, where its volume was determined by hydrostatic weighings.

Forty cylinders were then prepared to become the national prototypes. Seventeen of these were found so defective that the chemist Debray was commissioned to remelt and correct them. Several from the staff of the Pavilion of Breteuil, and especially MM. Marey and Benoit, made the numerous determinations necessary in the study of these prototypes and their comparison with the international standard. M. Guillaume is still occupied with the study of methods of improvement. During 1898 this

able physicist published some interesting work on nickel steels, and their application to metrology. Some of these alloys have very low coefficients of expansion, are not subject to oxidation, are very homogeneous and take a fine polish. If the variations due to successive meltings are too great to allow this alloy to replace platinum iridium for the work of the highest excellence they are still so small as to allow its use of nickel steels for instruments of secondary importance.

We have now to add a remarkable undertaking of M. Michelson. This learned American by ingenious processes whose details we cannot here describe, has compared the fundamental base of the metric system with a natural unit, namely, the length of a wave of the red light of cadmium. This unit depends only on the properties of atoms and of the ether. It appears to be in the opinion of our author, "one of the most permanent magnitudes in all nature." His delicate experiments have given him the following mean values: One meter is equal to 1,553,164 wave lengths of this light at 15 degrees Centigrade and 76 centimeters pressure. So that man can say today, that if all our standards should disappear by some catastrophe, we should be able by working out the problem of Michelson in the reverse direction to re-establish by means of the results he has given us all the units of the metric system. Verily the French astronomers of the eighteenth century were not wrong in the importance they attributed to it, when they said it "was for all time and for all nations."

Notes.

BIBLIOGRAPHICAL.

The Canadian Boy (Turnbull, Wright Co., Guelph,) for September has an interesting "Natural History Corner," conducted by Prof. Lochhead, of the Ontario Agricultural College. Mr. A. W. Wright, who has lately assumed the editorial duties in connection with this periodical, deserves congratulation upon the improved appearance of the paper, which is now a beautifully printed magazine of 64 pages. Prof. Lochhead's department will give the boys of Canada an increased liking for insect and plant studies.

E. L. H.

The Canadian Forestry Association has recently issued the report of its second annual meeting. In addition to valuable papers on the problems of forestry, we are glad to notice that the educational side has not been neglected. Dr. A. H. Mackay, of Halifax, furnishes some notes regarding the teaching of some of the elementary principles of forestry in connection with manual training woodwork. And Dr. Muldrew, of Gravenhurst, has a good paper on *Forest Botany in Schools*. The report forms an attractive pamphlet of 64 pages, the cover being of appropriate and tasteful design, beautifully executed.

E. L. H.

Chemistry teachers, as well as *physiography* and *geology teachers*, have long felt the want of a book that would give just what is essential about useful ores and rock-bearing minerals. This want has been recently filled by the appearance of a little book (*The Practical Study of Common Minerals*), which bears on every page the stamp of practicability and usefulness. Mr. Hopping, the author, seems to understand perfectly the needs of the teacher, and has produced a book that is both suggestive and helpful. It not only gives descriptions, illustrated with plates and maps of the common and useful minerals, but also contains much that can be done in the laboratory in the way of tests. (It is for sale by "The School Science Press," Ravenswood, Chicago, Ill. Price, 60 cents.)

Botany teachers will be interested in a pamphlet by Mr. C. H. Robison, Oak Park (Ill.) High School, on *Outlines for Field Studies of Some Common Plants*. It was gotten out to serve as a basis for some observation work for first-year high school pupils. It is designed almost entirely for outdoor work, i. e., observations in ecology, or plant habits, and is built around material available in the autumn, a field hitherto little exploited. The work requires neither laboratory equipment nor periods of double length. In the Oak Park High School the work outlined in the pamphlet occupies the first three months, and is followed by work in the line of very simple physics and chemistry built around so-called "weather studies," all this leading up to the physiology required by law, the formal study of physiography not being favored in the first year of the high school.

BIOLOGY.

Proof of the leaf-nature of cotyledons is nicely shown in germinated Windsor beans with an epicotyl even half an inch long. They show buds in their axile, and pupils may be led to see these after learning the significance of "buds in the axile."

L M

To Study the Effect of Colored Light on Growing Organisms.—A simple substitute for the more expensive double bell-jar may be made by using two test-tubes of slightly different diameters. Place the smaller tube, containing the organism, in the larger and fill the intervening space with a colored fluid. Cover the top with a dark cloth. For a blue light, copper sulphate solution gives good results; for red, eosin. If a larger vessel is desired, slender dishes or any large glass dish may be used instead of test-tubes.

Detroit Central High School. ELONIA ANDRE.

An Improvised Hot-Water Funnel.—Not having at hand a hot-water funnel for filtering gelatine, one was improvised in a few minutes, and the device may be of service to others. An ordinary tin funnel is provided with a perforated cork in its neck in such a position as to hold upright a smaller glass funnel inside; this allows a hot-water space between the two funnels. The lower end of the tin funnel is made water-tight over the projecting tube of the glass funnel by means of a piece of rubber tubing, wired, if necessary.

After filling the space between the two funnels with water, a Bunsen burner or alcohol lamp is set under the slant of the tin funnel, and filtering can proceed for nearly an hour without replenishing the water. A cover over both funnels will keep the water in and the dust out.

L M

Seed Distribution in the Classroom.—This is a convenient time for collecting and using dry seed-like fruits and seeds that are scattered by the wind. The *means* the seeds employ may be nicely shown a whole class in the schoolroom by dropping these seeds from the ceiling of the room. For this purpose one of our better pupils was given a horn scale pan, a screw pulley, some string, and an idea of what was wanted. He fastened the pulley to the moulding near the ceiling, and passed over it the string, reaching from the floor over the pulley and back to the floor. One end of the string was tied into the S-hook supporting the scale pan by three cords. The other end was fastened so as to keep it within reach. Another string was tied into one of the three holes on the edge of the pan and drawn up through the S-hook. This string was fastened to the wall at such a distance from the ceiling that when the pan was up near the pulley the pull of this string upset the pan. It will be seen that the upsetting of the pan, thus throwing out the seeds, is automatic. With a large fan the *agency* of the wind can be imitated while the seeds are descending.

L. M.

GEOGRAPHICAL.

The director of the geological survey of Canada states in his last report that practically nothing is known about more than a third of the Dominion of Canada. A part of this unknown region consists of the Arctic islands, but there is nearly a million of square miles of territory exclusive of these islands which is practically unexplored. Here is indeed a field for the geographical explorers and one which would seem to be more easy of conquest than the interior of Africa.

Sir Harry Johnston is reported to have discovered in Unganda a hitherto unknown animal. It is called the Okapi and belongs to the giraffe family. It is rather closely related to some fossil forms found in Greece and Asia Minor. The animal is about the size of a large ox. The color of the animal is very peculiar, the body is a reddish color, but the legs and hind quarters are striped in purplish black and white. The same explorer also reports the discovery of an ape-like people in central Africa. They have "a dirty yellow skin, a poor development of the back of the head, eyes rather close together, with prominent eyebrows, low and wrinkled foreheads. The hair is woolly, like that of the ordinary negro, though it sometimes tends to be brownish in color. The arms are long and the thumbs weak. The legs are a little knock-kneed, and are often very short in proportion to the body."

An ethnological expedition under the direction of Prof. Baldwin Spencer of Melbourne University and Mr. F. J. Gillies is studying the aborigines inhabiting Central Australia. A considerable portion of this region remains unexplored and it is very desirable that as much as possible should be learned about the manners and customs of the inhabitants, who will probably before many generations become entirely extinct.

A new Dead Sea has been discovered in Tibet by Sven Hedin, the Swedish explorer. The margin is very shallow, being but a few feet deep at the distance of over a mile from the shore. The bottom is a compact mass of salt. The entire lake is a practically saturated salt solution. The region around the sea is sterile.

Word has recently been received from Lieutenant Peary. He has circumnavigated Greenland and discovered the most northern land thus far found. He attained the highest latitude ever reached in the western hemisphere, 83° 50′ north. He has also determined the origin of the "floe bergs" or paleocrystic ice. Lieutenant Peary expects to remain for another year in the north and make another attempt to reach the pole.

The village of Vaglio in the Etruscan Apennines, containing 900 inhabitants, began at about 3 p. m. on March 21 to slide into the valley of the Scoltenna. The rate of sliding was about 10 inches an hour. The movement of the soil produced great waves at the front which engulfed houses and trees. During the night of the 23rd the river rose, forming a lake covering the former site of the village. The movement was so slow that the inhabitants were able to save their movable property.

W. H. S.

Book Reviews.

A Hand-Book for Teachers of Chemistry in Secondary Schools. By J. A. GIFFIN, B. A., LL. B., Collegiate Institute, St. Catharines, Ont. 12x17.5 cms., vi and 75 pages. William Briggs. Toronto, 1900. 60 cents.

The author gives a unique and original method of teaching the chemical equation, basing it upon experiment and graphic representations. Much that is suggestive will be found in his treatment. The author also gives his experience in dealing with and overcoming the difficulties of handling noxious gases, and numerous valuable hints on apparatus. Teachers of chemistry should profit much by reading this book.

Chemical Lecture Experiments. By FRANCIS GANO BENEDICT, Ph. D., Instructor in Chemistry in Wesleyan University. 13x19 cms., xiii and 436 pages. The Macmillan Co. New York, 1901. $2.

With the spread of the laboratory method in the teaching of chemistry came a neglect of experimental demonstration by the instructor at the lecture table. The pupils must handle everything, their knowledge of the subject must be gained through their own experimental work, supplemented by a study of their text book, has been the thought and aim of most teachers. There can hardly be a doubt that this has been carried to extremes. As Dr. Benedict says in his preface: "Laboratory exercises, however great their influence in developing the experimental side of teaching the science, have their limitations, experimentally and educationally, and cannot supplant the experimental lecture, for it is in the lecture, and there only, where each experiment stands out clearly defined and unattended by the distractions necessarily accompanying laboratory exercises, that the first accurate observations of chemical phenomena can be made by students."

Perhaps another reason that lecture-table demonstrations have been neglected is the lack of a guide to them. The books of Heumann, Arendt and Newth have, indeed, been at hand, but there is a certain "foreignness" about them that seems to have stood in the way of their general use in American schools. Dr. Benedict's book, however, admirably corresponds to the limitations of our lecture-table apparatus, for it particularly tries to choose simple and readily constructed pieces of apparatus so as to tax as little as possible the teacher's time and ingenuity. The directions are plain and simple, and ensure the successful performance of the experiment. A number of novelties also are found, which put the book in advance of others of the same kind.

The book ought to find a place upon the work table of every teacher of chemistry. Many of the experiments, even if not demonstrated, can be put into the hands of students with excellent results. The book will undoubtedly prove a splendid aid to effective teaching.

C. E. L.

A Laboratory Course in Plant Physiology. By Dr. W. F. Ganong. Professor of Botany, Smith College. 15x22 cms., vi and 147 pages. Henry Holt & Co. New York, 1901. $1.

This book provides an excellent course of laboratory work in plant physiology designed to cover a college year. The author, who at the same time is a most effective teacher, has plainly put much time and thought on the matter before printing the book. The experiments outlined can be performed to a large extent with apparatus that can be provided at moderate expense and bears witness to much ingenuity in their designing. The plan of the work is drawn in decided lines and a marked character is thereby imparted to the book which will challenge the attention of the thoughtful teacher. All in charge of botany in high schools in which the newer methods have found foothold, will find much to reward an examination of Dr. Ganong's book.

Rodney H. True.

Practical Text Book of Plant Physiology. By Daniel T. MacDougal, Director of the Laboratories of the New York Botanical Garden. 13x21 cms., 252 pages. Longmans, Green & Co. New York, London and Bombay, 1901. $3.00.

The lack of suitable elementary English text books dealing with the fundamentals of Plant Physiology has been increasingly felt by instructors in botany as this phase of plant study has come more and more to the front. This book, presenting, as it does, a concise discussion of the underlying principles and directions for a course of laboratory work, aims to meet the need felt. The work is essentially a book for use in college grades, and will prove very suggestive for science teachers in the secondary schools.

The discussion proceeds from a thoroughly modern standpoint and the citations of recent work will prove very useful. Some unfortunate errors have crept in which should be corrected in later editions. The laboratory experiments are on the whole well selected and clearly outlined. In every way the book marks a distinct advance over the author's earlier book on the subject.

Rodney H. True.

Sylvan Ontario. A Guide to Our Native Trees and Shrubs. By W. H. Muldrew, B. A., D. Pæd., Principal of the High School, Gravenhurst, Ontario. 14x20 cms., 70 pages. William Briggs, Toronto, 1901. 50 cents.

This useful little volume is the result of practical educational work done by Dr. Muldrew. Many readers of School Science will remember

a paper on *"Forest Botany,"* appearing in the April issue. Owing to encouragement received from all quarters, Dr. Muldrew has now put into available form his scheme of identification of trees and shrubs by their leaves. The essential part of the book is "An Index Based on the Leaves," which is used in the same way as a botanical key. This index is preceded by a synopsis of leaf and stem terminology, which is illustrated by references to the numerous outline drawings which appear as alternate pages of the index. These outline drawings are of assistance to the pupil in his diagnosis. The index is followed by a list of shrubs and trees, containing appropriate notes on each.

The prevailing ignorance in regard to our common trees ought to disappear if the book continues to meet with the wide sale which it merits. It has already been put to the test by several teachers of experience and has been found to give excellent results in the hands of even junior pupils. A very little instruction ought to enable a boy or girl to use it intelligently.

Though the author has called his book *"Sylvan Ontario,"* its usefulness is by no means confined to the province. The similarity of the floras of neighboring states will make it useful for a very large portion of the continent.

Besides the cloth covered edition, the publisher has issued a very artistically bound edition in soft leather, at one dollar. The press-work and paper are all that can be desired. The work is highly creditable to the publisher whose advertisement appears in this issue.

E. L. H.

Foundations of Botany. By JOSEPH Y. BERGEN, A. M., Instructor in Biology in the English High School, Boston. 13x19x37 cm., xi and 412 pages; with which is bound *Bergen's Botany, Key and Flora*, ii and 257 pages. Ginn & Co. January, 1901.

This book is avowedly an amplification and revision of the author's *Elements of Botany* issued several years ago. The success of the earlier work was evinced by the ready sale and wide distribution which it enjoyed. This condition has brought to light many suggestions and ideas now more or less fully incorporated in the new work. The first part of the book is concerned with the structure, physiology and classification of plants. The study of the structure and physiology begins with the seed and its germination, and passes more or less regularly through the developing parts of higher plants to the mature fruit. The great feature of Mr. Bergen's treatment of these related subjects is truly pedagogical, quite in contrast to their separation in many modern botanies, and to the methods of as many secondary schools claiming to be up with the times. He makes a great point of structure and function being interdependent and simultaneous. He has gone on the principle of showing that structures are for a purpose, and that functions are carried on by these very structures. Between the

study of leaves and the study of inflorescence, the author has introduced a chapter on "Protoplasm and its Properties," which produces a perceptible break in the first eighteen chapters. From the point of view of construction, it would have been better to have placed this chapter either before or after those mentioned, leaving more evidently to the choice of the teacher the introduction of this chapter according to the conditions of the course. The classification of plants is discussed in a short chapter, in general, together with two tables illustrating the use and value of the taxomomic terms "cryptograms," "thallophytes," "gymnosperms," "class," "order," etc. The remaining four chapters treat of the structure and somewhat of the actions of representative types of flowerless plants, together with a short discussion of the history of plants in time. Now it would seem that the student should be led by stages through these groups, and then to the broader question of plant relationships. This logically would place the chapter on classification at the end of Part I. A marked improvement of this book over its predecessor is the fuller treatment of, and the added experiments illustrating, plant activities, and in a fuller complement of cryptogams. There is now a better balance between seed plants and spore plants, there being no doubt the educational value of the study of one is as great as of the other group.

Part II. is concerned with "Ecology, or the Relations of Plants to the World About Them," "Plant Societies," "Botanical Geography," "Parasites," "Carnivorous Plants," "How Plants Protect Themselves," and others, are the chapter headings. A chapter on "The Ecology of Flowers" deals not so much with the flowers as a whole as with modifications of their parts for their pollination through the agency of wind, insects, etc.; and, in contrast to these, with cleistogamous flowers. The season of the year, the advancement of the class, and the accessibility of the fields must determine the introduction of these problems of ecology into the other parts of the course. Any bright teacher would instantly see that plant ecology has close relations with structure and activity. This part was in some degree included in the general part of the *Elements of Botany*, but now, following the lead of other recent authors and botanies, is separated from the other subjects, presumably for the emphasis now being given to the ecological side of Nature Study.

The Key and Flora comprises about 700 species belonging to the gymnosperms and angiosperms. It is gratifying to see that after studying about plants from the known to the unknown, the student is given the use of a manual descriptive of them, which is arranged in the order of the simplest to the highest, thus calling his attention to their true relationship. The classification used is practically that of Engler & Prantl. The nomenclature is, with a few exceptions, that of Gray's *Manual*. One condition of this nomenclature is without apparent consistency or explanation, viz., the capitalization of specific names derived from the names of men and names of genera other than those containing the said species, while specific

names derived from geographical ones are not capitalized. This *Flora* is illustrated, in connection with the keys, by figures representing the more complex and less understood structures. The keys in the main are artificial. With the fuller treatment of the cryptogams in the text-book, there seems to be a lack in the *Flora's* not containing at least some forms of the flowerless plants. The educational value of the determination, if not farther than to genera, of fernworts and the larger mossworts, particularly after the study of their morphology, is as great as in classifying flowering plants, to say nothing of the additional knowledge.

The typography and illustrating are a great improvement over the older work. The binding of the copies we have seen, while artistic, is hardly suitable for the unavoidable soiling in laboratory and field.

E. L. M.

CLEARING HOUSE.

Teachers desiring to offer for exchange books, apparatus, etc., may insert a notice to that effect at the nominal rate of one cent per word, *in advance.*

Reports of Meetings.

N. E. A. ROUND TABLE CONFERENCE IN PHYSICS.

THURSDAY, JULY 11, 3 P. M.

Mr. Carl I. Ingerson, Normal and High School, St. Louis, *Leader.*

Mr. H. D. Minchin, Central High School, Detroit, *Secretary.*

The conference was called to order by the chairman, who, after stating the object of the meeting, read a paper entitled, "Physics in Secondary Schools." (See page 288.)

Discussions were now in order and the following are in brief the remarks of the different speakers:

MR. A. W. AUGUR, Lake View High School, Chicago: "In my remarks I wish to speak briefly of two tendencies at present existing in the teaching of physics.

1. At present there is a crowding of too much work into the course. We attempt to teach too much for the time we have at our disposal. We

are crowding two years' work into one. The result is that work is not done well; there is a skimming over. It is absolutely necessary that the student be given more thorough drill and therefore he should not be overcrowded. It is for the teacher to carefully select that which is to be given him and that which he is to overlook. The time at present given to physics in the high school is not sufficient to allow the taking up of the whole subject of physics.

2. The present method of dividing the subject matter into heads, as Mechanics, Heat, Sound, etc., is misleading to the student. He comes to think of the study as a collection of several subjects. We must get an underlying principle, one that we may cling to in the different sub-heads. At the present I am working for such a plan and I take as the definition of physics the following: It is the science that treats of the motions of matter, all motions being considered as the result of the action of forces, and all forces as the manifestations of energy. If we keep this definition in mind it changes the order of presenting the subject.

We will not take up the properties of matter first but will begin with motion. The pupil never saw a case of uniform motion; there is no such thing as pure mechanics or pure dynamics. We should take as our first example of motion a vibratory motion. This is almost exact and can be measured. Discuss uniform motion as growing out of this and sound as a particular kind of uniform motion; heat also as a particular kind of the same phenomenon, etc. This will unify the work and keep it within our limits.

In regard to laboratory experiments I hold that there are but two reasons for performing an experiment:

1. It illustrates a law.

2. The results obtained by performing it are essential for future experiments.

Do not ask the pupil to perform experiments that are of neither class. Do not ask him to measure a piece of wire unless he is to use the wire and needs to have its length. He should learn how to use it in a practical exercise.

As to the amount of laboratory work we are in great danger of asking the pupil to do too much. We should aim to have him do a few exercises well rather than a number and do them with no idea of what they may mean or of what use they are."

Mr. E. A. Thornhill, Carrollton, Ind.: "I am at present endeavoring to re-organize my work in physics and I wish to ask what amount of time should be given to laboratory practice."

Mr. C. F. Adams, Central High School, Detroit, Mich.: "I heartily endorse the paper to which we have just listened. I think much better results would be obtained if we were to begin our work with motion and we should not be afraid to begin here.

I believe we have better results from our laboratory if we keep in

mind that there are many facts and truths that are now well established and need no further proof by the pupil.

In answer to the question just asked I will say that we have four recitation periods per week for text work and two periods per week for laboratory work. We should have more time. We ought to have five recitations in the text, as we now have to take one of the four for discussing the laboratory exercise of the week. Then we should have at least two periods of 60 minutes each per week for laboratory where we now have but two of 45 minutes each. In this state we have laid down as a minimum amount of work for the laboratory a list of about 40 experiments. The time now given to these is not sufficient to cover the work as I think it should be covered. Our work lacks in completeness. We lay a good foundation, but the superstructure is lacking.

In speaking as I am, I speak not as a teacher of physics only, but as a teacher interested in the high-school course. In the small schools where much individual work can be done more may be accomplished in the same time."

MR. H. N. CHUTE, Ann Arbor, Mich.: "My sympathy is with the paper just read and I am glad of the interest shown in the points called forth.

Our great difficulty with the subject of physics is that the boys and girls think they have taken hold of a new language. They get the idea that it is a compilation of hard words. It is in a sense a foreign language to them. The sentences that are plain to us are, it may be, meaningless to them.

We must translate this language for them and then require them to translate it back into the language of physics.

We experience other difficulties in the teaching of physics because of the fact that it is placed too low down in the course. The average boy and girl reach the 11th grade at about 15 and their minds are not mature. They are unable to grasp the subject. They get the idea that physics is a grind. The subject has been given a black eye long before it is reached and it takes a good half year to remove the fear that has seized the pupil. The parents and often the principals are to blame; they are anxious to crowd the pupil and he is not given the time to comprehend the facts. A lack of interest is the result.

I wish to emphasize what the paper stated regarding the amount of time given to the different parts. The boy is interested in the magnet and he wants his work all electricity. There is a tendency to skim over light and heat. Both the latter are of great importance and both can be illustrated easily and at small expense.

As to what experiments to perform I would like to ask where the pupil will land if he is to perform no experiment only that one, the results of which he is to use in the next experiment.

In my work I give 4 periods of 55 minutes each per week to text and 3 periods of 55 minutes each per week to laboratory.

I follow the outline prepared by the Michigan Schoolmasters' Club in 1899."

Mr. C. F. Adams "I heartily endorse the point that no work should be required of the pupil if it is to be of no use to him. Do not have him measure for the mere sake of measuring."

Mr. Herbert C. Wood, Cleveland, Ohio: "In reference to the mathematical preparation of the pupil with us no pupil is allowed to take up physics until he has had one year of algebra and the same of geometry.

Some of the difficulties I have met in the teaching of physics I find are due to the indifferent work done in the preceding studies. It is necessary that in geography, botany, physical geography, etc., more scientific work be done. We have in our schools introduced laboratory work in connection with physical geography and we find that better work is being done in physics."

Mr. Jones, South High School, Cleveland, Ohio: "Our requirements are the same as those of the Central. We have physics in the third year. I find a difficulty in getting the pupil to state in mathematical language an expression in physics and *vice versa*. The teacher of physics has as his first duty to teach how to change from a statement in physics to one of mathematics. Secondly he must teach that mathematical expressions do not teach that we can get at a thing exactly. The pupil sees in the laboratory that we can not get at an exact result."

Prof. F. A. Osborne, Olivet, Mich.; "As teachers we are too often afraid of having physics considered difficult. If we are to make the study intensely interesting and give the pupil the discipline he should get from it we must make it difficult. It is possible to add new interest and not detract from its value. It is well to introduce some historical facts. In every study there is encouragement in knowing of the difficulties others had with the subject. Devote one-half hour per week at least to the history of the subject.

As to the use of problems in physics I find they are of untold value. My students work 250 to 300 problems each year and benefit by so doing.

Do not leave out the original work. We do not do so in geometry. The more we make physics difficult and not a grind the better. In the laboratory work I believe in doing fewer experiments and doing them well. I began by working 60, I now work about 40. I am decidedly in favor of working a few experiments the data of which are not required later."

Mr. A. P. Cook, Ithaca, Mich.: "I have a laboratory about 12x25 for 25 pupils. Ours is about a middle high school and we are placed under many restrictions. Our work must be shaped accordingly. I am in favor of working many problems. I believe in making the subject hard. Do not attempt to dodge all the hard points, but solve them and derive the

benefit. Tell the boys and girls to keep their eyes open and be ready to apply what they have learned."

MR. H. N. CHUTE, Ann Arbor, Mich.: "The question that troubles me is where to get the wherewith to teach physics. . I mean good and efficient instruments. Our foreign friends make them, but Uncle Sam says we cannot have them unless we pay large tribute. Our lawyers seem to be unable to interpret the law. They do not understand English. They fail to be able to recognize a scientific instrument. We should look up the law and then translate ourselves into chronic kickers. It is time for the scholar to get into politics."

MR. ADAMS: "It seems that some protest should be made by the N. E. A. and I therefore move that we enter a protest and present it to the Secretary and Treasurer of the U. S. and that our chairman appoint a committee to draw up said protest and present it to the proper authorities."

The motion carried. Chair appointed Messrs. Adams, Augur and Wood, the committee to report at the meeting July 12. It was suggested by Prof. Osborne that each member of the Physics Conference present to his Congressman a copy of the report of the committee, together with his own letter. The suggestion was favored by those present.

Correspondence.

CIRCULATION OF BLOOD IN A FROG'S FOOT

In SCHOOL SCIENCE (Vol. I. page 219) it is suggested cutting the head of a frog off and wrapping it in a wet cloth to demonstrate circulation. This is a good method, but I have always simply wrapped the frog in a wet cloth, leaving one hind leg exposed. Then I lay it on a glass plate about 7x9 inches, supported by the stage of the microscope and a chalk box. In this way I have had no trouble in keeping the frog quiet, and, of course, could use the frog day after day as long as desired. The frog's foot will adhere to the glass so that there is usually no trouble in keeping the web stretched. Sometimes, however, I have stretched out the web and laid a glass slide on the ends of the toes. This may be fastened down with two pinch-cocks provided with small rubber tubing over the jaws to keep them from slipping off the glass.

Hope College, Holland, Mich. S. O. MAST.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

DISCUSSION OF QUESTIONS.

26. *What is the best material for a chemical table top—wood, glass, tile, soapstone, or what?*

If it can be afforded, soapstone tops are by far the best for a chemical table top. I have now had in use for three years soapstone tops (of the variety known as "Albarene") and they are not merely practically but are actually as good as new. Chemicals and heat seem to have had no action upon them. They can be made to look as good as new by application of sandpaper once or twice a year. The objection which might be raised that they are too hard and that glassware is easily broken on them, my experience does not sustain. The side tables in my laboratory are of slate, and it is quite noticeable that glassware used on them is liable to be broken by setting it down a little too hard, although nothing of the sort is observed on the soapstone tops. Slate, by the way, cannot be recommended. Apart from its hardness on glassware, it is attacked slightly by acids, so that it soon scales off, leaving a rough surface. Glass tops I have had no experience with, but would think that they would be liable to break from heat or strain, and would soon be all scratched up without the remedy of sandpaper. Wood tops are, however, not to be despised. Even a soft wood like pine, if rubbed over with hot paraffine from time to time, proves very serviceable, and hardwoods, especially sycamore and oak, can withstand quite rough usage for a long time. Tile tops if well laid are excellent, if poorly laid, a nuisance. They are especially to be recommended for side tables in front of a window where volumetric work can be done, as in titration, the white surface aids in sharply distinguishing the end reaction.

C. E. L.

28. *Does the presence of iron, as gas pipes, bolts, etc., in a physical table top interfere with the success of the experiments in electricity and magnetism given in the usual course in elementary physics?*

No, if the apparatus when once set up is not moved to another part of the table. Galvanometer needles may indeed not point north, but they will point in some definite direction, and as long as the magnetic substances influencing the needle are not displaced, that direction will be maintained. Of course, with certain delicate magnetic experiments, proximity to iron, etc., is not permissible, but these experiments are not suited for the high-school laboratory.

C. E. L.

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THE APPLICATION OF STATISTICS TO EVOLUTION STUDIES.

BY CHAS. B. DAVENPORT.

Professor of Zoology, University of Chicago.

As an illustration of an application of statistics to evolution studies I will give some account of my work during the past two years on the scallop of our east coast, *Pecten irradians*.

Pecten irradians is a bivalve mollusc of flattened, lenticular form, that inhabits our coast from Cape Cod southward. The Cape Cod limit is a rather sharp one, but southward our scallop passes gradually into the closely related forms of the South American coast. This fact would seem to indicate its southerly origin. To get light on the evolution of the group, I have studied and measured over 3,000 shells, chiefly from four localities: (1) Cold Spring Harbor, Long Island; (2) Morehead, North Carolina; (3) Tampa, Florida, and (4) the late Miocene or early Pliocene fossils of the Nansemond River. The fossil shells, to which I shall frequently refer, were found imbedded in the sand at Jack's Bank, one mile below Suffolk, Virginia. The bank rises to a height of 25 to 30 feet. Shells were obtained from three layers, respectively, one foot, six feet and 15 feet above the base of the bluff. Of course, the upper shells lived later than the lower ones and may fairly enough be assumed to be their direct descendants. The time interval between the upper and lower levels cannot be stated. As I have measured sufficient shells from the bottom

and top layers only I shall consider them chiefly. I wished to get recent *Pectens* from this locality, but the nearest place where they occur in quantity is Morehead, North Carolina. These *Pectens* may therefore stand as the nearest recent descendants of the *Pectens* of the Nansemond River.

The *Pecten* shells have a characteristic appearance in each of the localities studied. After you have handled them for some time you can state in 95 per cent. of the cases the locality from which any random shell has come. First of all, the shells differ in color, especially of the lower valve. In the specimens from Cold Spring Harbor this is a dirty yellow; from Morehead, yellow to salmon; from Tampa, white through clear yellow to bright salmon. Second, the antero-posterior diameter of the shell becomes relatively greater than the vertical diameter as you go north. Thus, the antero-posterior diameter exceeds, on the average, the dorso-ventral diameter: at Tampa, by about 1.5 mm.; at Morehead, 2.5 mm.; and at Cold Spring Harbor, 6 mm. The fossil *Pectens* have an excess of about 4 mm.

Comparing the fossils with the *Pectens* of Morehead we find, as shown above, that the fossils are more elongated. Comparing the depth of the right valves having a height of 59 mm., we get:

From the lowest level, Jack's Bank	8.8 mm.
From the highest level, Jack's Bank	9.1 mm.
From Morehead	19.7 mm.

Hence the recent shells are much more nearly spherical than the fossils; there is a phylogenetic tendency toward increased globosity.

The average number of rays in the different localities is as follows:

Lower level, Jack's Bank	22.6
Middle level, Jack's Bank	22.1
Upper level, Jack's Bank	21.7
Morehead and Cold Spring Harbor	10.3
[Tampa	20.5]

Here it appears that there is a phylogenetic tendency toward a decrease in the number of rays of *Pecten irradians*. To summarize: The scallop is becoming, on the average, more globose,

and the number of its rays is decreasing and its valves are probably becoming more exactly circular in outline. The foregoing examples illustrate the way in which quantitative studies of the individuals of a species can show the change in its average condition both at successive times and in different places.

But the quantitative method yields more than this. It is well known that if the condition of an organ is expressed quantitatively in a large number of individuals of a species the measurements or counts made will vary, *i. e.*, they will fall into a number of *classes*. The proportion of individuals falling into a class gives what is known as the "frequency" of the class. Now it appears that in many cases the middle class has the greatest frequency (and is consequently called the mode) and as we depart from it the frequency gradually diminishes, and diminishes equally at equal distances above and below the mode. One can plot the distribution of frequencies by laying off the successive classes at equal intervals along a base line and drawing perpendiculars at these points proportional in length to the frequency. If the tops of these perpendiculars be connected by a line there is produced a 'frequency polygon.' The shape of the frequency polygon gives much biological information. When the polygon is symmetrical about the modal ordinate we may conclude that no evolution is going on; that the species is at rest. But very often the polygon is more or less unsymmetrical or 'skew.' A skew polygon is characterized by this: that the polygon runs from the mode further on one side than on the other. This result may clearly be brought about by the addition of individuals to one side or their subtraction from the other side of the normal frequency polygon. The direction of skewness is toward the excess side. The skew frequency polygon indicates that the species is undergoing an evolutionary change. Moreover, the direction and degree of skewness may tell us something of the direction and rate of that change. There is one difficulty in interpretation, however, for a polygon that is skew may be so either from innate or from external causes. In the case of skewness by addition we may think that there is an innate tendency to produce variants of a particular sort, representing, let us say, the *ataxistic* indi-

viduals. In this case skewness points to the past. The species is evolving *from* the direction of skewness. In the case of skewness by subtraction there are external causes annihilating some of the individuals lying at one side of the mode. Evolution is clearly occurring away from that side and *in* the direction of skewness.

Now so far as we know at the present time there is no way of distinguishing skew polygons due to atavism from such as are due to selective annihilation. But in many cases at least the skewness, especially when slight, can be shown to be due to atavism; and this is apparently the commoner cause. This conclusion is based first upon a study of races produced experimentally and whose ancestry is known, and secondly upon certain cases of compound curves. Take the case of the ray flowers of the common white daisy. A collection of such daisies gathered in the fields by De Vries gave a mode of 13-ray flowers with a positive skewness of 1.2. The 12- or 13-rayed wild plants were selected to breed from, and their descendants, while maintaining a mode at 13, had the increased positive skewness of 1.9. The descendants of the 12-rayed parents had a stronger leaning towards the high ancestral number of ray flowers than the original plants had. The 21-rayed plants were also used to breed from. Their descendants were above the ancestral condition as the descendants of the 12-rayed plants were below. The skewness is negative (—0.13) although comparatively slight. In this case we have experimental evidence that polygons may be skew *toward* the original ancestral condition.

Of the compound polygons it is especially the bimodal polygon that frequently gives hint of two races arising out of one ancestral, intermediate condition. Consequently we should expect the two constituent polygons to be skew in opposite directions; and so we usually find them to be. For example, Bateson has measured the horns on the heads of 343 rhinoceros beetles and has got the bimodal polygon. The polygon with the lower mode has a skewness of + 0.48; that of the higher mode a skewness of —0.03. One might infer that the right-hand form, the long-horned beetles, had diverged less than the short-horned from the

ancestral condition. Again, as is well known, the chinch bug occurs in two forms—the long-winged and the short-winged. Now, in a forthcoming paper my pupil, Mr. Garber, will show that the frequency polygon of the short-winged form has a skewness of + 0.44, while that of the long-winged form has a skewness of — 0.43. On our fundamental hypothesis the ancestral condition must have been midway between the modes.

Still a third class of cases that gives evidence as to the significance of skewness is that where two place modes have moved in the same direction, but in different degrees. Thus the index (breadth ÷ length) of the shell of *Littorina littorea*, the shore snail, as measured by Bumpus ,has at Newport a mode of 90, at Casco Bay, of 93. The skewness is positive in both places and greater (+ .24) at the more southern point than at Casco Bay (+ .13). This indicates that the ancestral races had a higher index than even those of Casco Bay, probably not far from 96, and also that the *Littorina littorea* of our coast came from the northward, since the northern shells are the rounder. We have historical evidence that they did come from the northward. Likewise the *Littorinas* from South Kincardineshire, Scotland, have a modal index of 88 and a skewness of + 0.065, while those of the Humber, with a mode of 91 have a skewness of + 0.048 These figures suggest that if the mode were 97 the skewness would be 0, and this would give practically the same value to the ancestral index, as arrived at from the *Littorinas* of our coast. It will be seen from these illustrations that the form of the frequency polygon may be of use in determining phylogeny.

While skewness is thus often reminiscent, we must not forget the possibility that it may be, in certain cases, prophetic. This has come out rather strongly in a piece of work I have been engaged on during the past year. I have been counting the number of rays in recent *Pecten irradians* from various localities and have obtained in some cases evident skewness in the frequency polygons. To see what phylogenetic meaning, if any, this skewness has, I sought to get a series of late fossils. After careful consideration I was led to go to the Nansemond River for the late Tertiary fossils found there and already referred to. These

served my purpose admirably. We may now compare the average number of rays from the two extreme layers at Jack's Bank and at Morehead with the indices of skewness of the frequency polygons from the same localities.

PLACE	AV'G NO. OF RAYS	INDEX OF SKEWNESS	s
Morehead, N. C.....	17.3	—0.09	0.81
Upper Layer, Jack's Bank	21.7	—0.16	1.0
Lower Layer, Jack's Bank	22.6	—0.22	1.24

This series is instructive in that it tells us that the gradual reduction in the number of rays has been accompanied at each preceding stage by a negative skewness. This skewness was thus *prophetic* of what was to be. The skew condition of the frequency polygon we may attribute to a selection taking place at every stage, and the interesting result appears that the selection diminishes in intensity from the earliest stage onward. It is as though perfect adjustment were being acquired. If adjustment were perfected, we might expect a decrease in the *variability* in the rays at successive periods. And we do find such a decrease. This is indicated in the last column where s stands for the index of variability. From this column it appears that the variation in the number of rays has diminished from 1.24 rays in the Miocene to 0.81 rays in recent times. This fact again points to an approach in perfection and stability on the part of the rays. Just why or wherein the reduced number of rays is advantageous I shall not pretend to say. It is quite possible that it is not more advantageous, but that there is in the phylogeny of *Pecten irradians* an inherent tendency towards a reduction in the number of multiple parts. As a matter of fact there are other *Pectens* in which the number of rays is less even than in *irradians*.

The reduction in the variability of the rays with successive geological periods has another interest in view of the theory of Williams and of Rosa, according to which evolution and differentiation have of necessity been accompanied by a reduction in variability. Evolution consists, indeed, of a splitting off of the extremes of the range of variation, so that in place of species with

a wide range of variability we have two or three species each with a slight range of variability. In the particular case in hand, however, it is not certain that the lower Jack's Bank form-unit (named *Pecten eboreus* by some one) has given rise to any other form than something of which *Pecten 'irradians'* of Morehead is a near representative. The evidence indicates that the reduced variability is solely the effect of the skewing factors.

The upshot of this whole investigation into the biological significance of skew variation is then this: Skewness is sometimes reminiscent and sometimes prophetic. In our present state of knowledge it is not possible by inspecting a single skew curve to say which of the two interpretations is correct in the given case. But by a comparison of the frequency curves of allied form-units the state of affaairs can usually, as in the examples given, be inferred. A method of interpreting the single skew curve is a discovery for the future.

ASTRONOMICAL OBSERVATIONS IN GEOGRAPHY.

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Efforts to improve the teaching of geography in the elementary public school have been numerous and varied among us. Nor does the present exhibit any abatement of them. The present tendency, however, seems to be setting strongly in the direction of physical geography. This paper is confessedly an effort to show that more observational work should be done in the teaching of what may be termed astronomical geography.

Probably the strongest argument for such work is to be drawn from the almost uniformly unsatisfactory answers given by high-school graduates to geographical questions involving a concrete knowledge, as opposed to a verbal knowledge, of such easily demonstrable facts as the earth's daily motion on its axis. Correct mental images of the earth as a sphere, and of the position

of the plane of the observer's horizon in all latitudes, are not derivable from the committing of the formal phrases and diagrams of a book. Certainly not one student in a hundred who has been taught geography according to present methods is able to imagine for himself with any degree of adequacy the dependence of daily phenomena upon the observer's latitude—and is this not quite as valuable to him as the commonly current dallying with the papooses of the Esquimaux? It would seem that the connection of such facts as the latter typifies with the latitude, although real enough, are too accidental, not to say silly, to justify the time commonly spent upon them.

Of course we teach how to compute the position of the sun relative to the horizon in different latitudes. Perhaps we even draw diagrams showing the decrease in the daily total of calories as we pass northward in latitude. But the proof that all this remains mere words, wholly inconvertible by the pupil into anything like a panorama, is found in the well-nigh unformly incorrect answers to questions concerning phenomena within the arctic circle. Let the problem be set. In a place having three months of consecutive daylight and three months of consecutive night, what circumstances as to light and darkness prevail during the remaining six months? The common answer will be, "The remaining six months are twilight" Generally, though not always, these six months of twilight are said to occur in two periods of three months each, one previous to, and the other subsequent to, the "long night." The palpable ignorance here shown of the most fundamental and regular daily occurrence, or perhaps better, the absolute inability to apply what every child must know full well as a verbal statement; viz., the earth's rotation, is incredible to any one not familiar with the facts.

How can this and similar evidences of ignorance be at least measurably remedied? In the writer's opinion the only way out of the difficulty lies through simply observing for a period of years during the later grades and high school the more obvious phenomena of the daily and nightly sky.

To carry this out it is quite unnecessary that the pupils should do their star-gazing in groups. The better plan is to draw upon the board, a few at a time, some twelve or fifteen simple diagrams

of star-groups to be used by the pupils as a guide in their surveys of the heavens. Pupils copy these diagrams and identify and verify them from their homes. The objective point of this work is to familiarize the pupil with the star-groups which mark the constellations of the zodiacal belt. And within certain limits it may almost be said that the fewer stars selected in each constellation the better. For elementary pupils the names of the individual stars is a matter of no consequence. The writer requires his pupils to learn the names of the first and a few second magnitude stars; not over twenty in the entire heavens visible in latitude approximately 40° N.

Thus, "three stars" mark Arias, Pleiades and Aldebaran, Taurus, Castor and Pollux, and Tejot (the only third magnitude star learned by name), Gemini; "four faint stars and a cluster," Cancer; "the Sickle, and the right-angled "Triangle with Denebola," Leo; "Spica," Virgo; "four stars," Libra; "Antares and its two companions," Scorpio; "the five stars of the inverted dipper," Sagittarius; "two stars, the upper apparently double," Capricornus: "the four stars of the Y," Aquarius; "the Pentagon," Pisces.

Of the constellations north of the belt, only the following are really valuable as guides to the zodiacal groups: 1. Polaris; 2. The Great Dipper; 3. Cassiopeia; 4. Vega in the Lyre; 5. The Northern Cross in the Swan; 6. "Altair and its two companions" in the Eagle; 7. Arcturus in Boötes; 8. "Capella and the Kids" in Auriga; 9. The Square of Pegasus; 10. "Two stars" in Andromeda; 11. Algenib and Algol in Perseus.

In the space south of the zodiacal belt we learn only the following: 1. Orion, by noting Betelguese, Bellatrix, Rigel, Saiph and the yard stick, or Belt; 2. Sirius; 3. Procyon.

With these objects definitely known in relation to each other, after a year of *occasional lessons*—one or two a month are sufficient—the mapping of the place of the moon and of the visible planets with reference to the nearest zodiacal star group or groups, from night to night, becomes a delightfully interesting and profitable exercise. The discussion of the observations, of course, falls always on a morning after a cloudless evening, and should constitute a part of the geography recitation.

The result of these observations is a fairly good, because a *concrete,* understanding of the following points: 1. The line of the moon's path among the stars; 2. The dates of its nodes, determining two points in the sun's apparent path, and so the earth's real path; 3. The rising and setting, and constant westering of *all* fixed stars every twenty-four hours; 4. The *eastward* course of the moon at the rate of 13° (about), and of the sun at the rate of 1°, every twenty-four hours; 5. The determination of the point of the winter solstice a few degrees west of the handle of the Little Dipper in Sagittarius, 28° *west* of the *constellation* Capricornus, and of the point of the summer solstice, at Tejat, 28° west of the constellation Cancer, showing the *fact* of the discrepancy between signs and constellations (the *fact* of precision, not the *theory,* at first); 6. The determination of the angles which the sun's rays make at midday with our horizon on the cardinal dates of the year.

After a few lunations have been observed and mapped by nights (each map, of course, is to be accompanied by data; *hour, day* and *month* of observation), the pupil has for the first time a concrete illustration of the *way* and *direction* of the sun in its apparent annual path among the stars. Never mind, at first, the problem of the nodes, and the 5° of inclination of the planes of the orbits of the earth and moon. It is quite enough, to begin with, that the student learn, by *his own observation,* that the moon travels *eastward* from night to night, in spite of its regular setting beneath our western horizon. That it travels at the rate of about 13° daily, he may be taught to deduce from his observations. And this fact, of having in addition to the "yard stick" a measure of *angular* distance across the heavens, becomes gradually a very helpful element in the observations. The apex of the angles in geometry is *objective,* so to speak, on paper; the apex of the angles, or degrees which we say lie between two celestial objects, is *subjective,* that is, in the eye, of the observer. And here also lies a much neglected opportunity, both in geometry and geography, that of cultivating the habit of correct imaging of angles. The ability to estimate the values of angles in terms of degrees is very necessary in expressing distances between the stars.

It seems quite superfluous to point out the obvious fact that the stars, by observing which we are helped to think rightly the phenomena of the earth's rotation and revolution, are always spread out before us at the time of greatest leisure, and may with little effort be satisfactorily observed and understood by young and old alike, from one's very doorsteps; while the data of physical geography, possessing also unquestioned educational value, are acquired effectively at best by a comparatively small number, and with considerable labor and exertion in studying the absolutely insignificant area in their vicinity, as a preparation for the elementary appreciation of the laws and forces that have fashioned the whole of the earth's surface. In both cases, it is generally admitted that effective thinking is possible for the majority only on the basis of observation. But whereas in physical geography only the most insignificant portion of the earth's surface is readily studied, in astronomical geography the great panorama of the heavens may be taken in almost entire with little physical effort. And it seems almost useless to think out the earth's two motions and the resultant phenomena without such observations.

There is also another class of observations which the children and teachers of every school should make each year with scrupulous regularity, viz.: of the *sunrise point,* and the *sunset point* at the cardinal dates. Let this be done, watch in hand, on the first cloudless morning and evening nearest each date; if done a day or two before, repeat it on or right after the date. For this it is best to agree upon some common spot, preferably the school house grounds, or a second story recitation room from which sunrise and sunset can be observed. The actual determination of the angle made at the place of the observer by the shifting of this point from December to March, and to June, in degrees, is as simple as the measuring of a line; we use a Prang triangle (10 cts.), which should be possessed by every student and teacher of geography. This, as much as any exercise, will aid in the right imaging of the actual space relations of the observer, standing on the arctic circle, and of the sun, during the twenty-four hours of June 21, and as well farther north.

Some of the most important facts of geographical knowledge are the cardinal dates, the cardinal points, the lines of latitude and

of longitude, the decrease pole-ward of the sun's heat, and the effect of this changing condition upon human existence in high as well as low latitudes. An effective understanding of them by the verbal textbook method, if not quite impossible, is yet exceedingly difficult with the great majority of young minds. And the removal of this difficulty lies, according to the conviction of the writer, in the direction of the simple observations suggested.

TRAINING FOR THE STUDY OF CHEMISTRY.

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Alchemy was the old study; chemistry is the new science. Before the latter could develope, experimentation was necessary. Experiments gave rise to facts. As the facts in the field of knowledge accumulated, it became necessary to classify and correlate them. The systematic arrangement and the development of relationships led to exact theory, the basis on which this science, as all others, now rests.

In experimental work there appears the general tendency for a great number of workers to be satisfied with a very restricted view of the subject, while the general perspective presents itself only to the few who by dint of genius and hard work have refused to be satisfied with the ordinary point of view. The latter in looking around should be able to discover the general position of the science, the points open to successful attack, or the positions which must be abandoned at the first severe onslaught of opponents. In a world and an age where lack of aggressive attack shows weakness of position or a feeble initiative, no leader of men can stand at ease, for the younger, more active and more restless elements are always eager to move and to feel that they are mov-

ing. They do not always demand a change of position, but desire progress and a different view of the territory already occupied and the successes already achieved.

To this restless element, then, to those who have been studying the strides made in chemistry in the past few decades, the question presents itself: In what way has the modern spirit of research with its new facts and new theories affected the presentation of the subject to those who wish to study it? If we admit that it takes a considerable period of time for the most carefully tested of modern views to find acceptance among teachers of teachers, we must not complain if the point of view of a university teacher is not that of the college or school man. The importance of the new fact or theory, its bearing on the previously accepted, the method or place of presentation, the interests of the hearers, and the immediate utility are all points which must be considered in the development of any science.

Of the older school of chemists, many, but not all, insisted on two points in their teaching work: the student must learn facts and he must learn methods. The great and omnipresent "Why?" was apparently not dwelt upon with so great an emphasis as now. In the first half of the nineteenth century, chemistry was taught by teachers of physics, anatomy, mineralogy, etc., as a secondary subject of little importance. It was in the experimental stage. Very few of its devotees could defend their claims that it was a *science.* The broadness, however, with which it was being presented and its connection with these other subjects has laid its foundations strong and sure. At a later date there came a change. Rapid development in all lines of applied work required specialists who were soon supplied by the universities. Specialization produced a separation from the study of botany, geology, anatomy, etc. There was, therefore, to be given to it a special method of pedagogy of which, unfortunately, the keynote as above sounded seems to have been facts, facts, facts—nothing valuable but facts.

The study then became restricted to a study of the changes of form and reactions of matter, the study of their properties serving mainly for analytical purposes. The accurate study of the physical

properties and the energies involved in reactions were ignored, since the specialization methods did not allow of development along the line to which so little interest was attached.

This accumulation-of-facts method was supplemented by a study of the methods employed by the chemist. Most of these had good foundation, their originators having understood more or less the underlying principles. The students, however, used these as many an artisan uses his tools—without stopping to think whether this tool was better than another, and if so, why. As illustration, we may take distillation work in the laboratory. Any one who has to deal with any chemical work knows that one of the most important means of separating compounds is by distillation; yet as a personal opinion, the writer would state his belief that not five per cent of the chemists of this or any country trouble their heads as to whether they are getting even respectable results for their labors when performing a distillation. Time is evidently not an asset. Methods then developed into rule receipts, such as are used in every chemical factory in the world. This is a result which will disappear only when the spirit of critical analysis is more thoroughly disseminated.

The effect of such methods of presentation shows itself on the teachers, but in a way far worse where the students are concerned. The walking-encyclopedia method can be adopted and used by those who have to do so, but the results are soon to be recognized in the attitude of the students toward the subject. Should they regard it as a bore, something which is studied because it is required, or even because it will give them a few extra facts which will teach them how to make explosive mixtures, flash powders, odorous bodies or other substances which the mischievous love to handle or the ingenious dare to make, the logical conclusion is that the teacher himself has not any idea of the subject being other than a bundle of facts, much less a science.

But how many teachers of today understand the problems of the science they try to present? How many know the laws and theories they endeavor to explain? How many understand the relationship of chemistry to the other branches of science? Do any ever stop to question whether it is an exact science?

These questions present themselves to all teachers and the replies as given by pupils themselves indicate that the old method of "facts only" persists and will persist. But what is the objection, what the difficulty, and what the hope of the future?

The problem is that chemistry has advanced from the stage where it studies reaction products alone, and has reached the position where the reaction itself is studied. How the reaction may be varied and studied in all possible variations is now one of the fundamental objects of chemistry. Chemists, like all other scientists, have to deal with varying conditions. They must know how to control conditions, if their work is to be successful.

What are some factors that they can vary? As chemists, they can always vary the material they start with—its nature and its amount. If, for example, they wish to make two grams of zinc sulphate, they take twice as much of the original material (e. g., zinc and sulphuric acid) as when only one was to be made; but should they wish to make zinc chloride, it is necessary to start with other materials, such as zinc and hydrochloric acid. This general plan is the one followed by men of the older school, and they certainly deserve all credit for their wonderful work and more wonderful results in producing new materials of strange properties and reactions. But other factors have to be taken into account. The chemist must know how to vary the conditions of temperature, pressure, light, magnetic field, electro-motive force, etc., in order to produce the results at which he aims. Should he wish to effect certain reactions—as the burning of sulphur in air—he must heat the sulphur, or should he wish to preserve liquid air he must cool it. Perhaps some hydrated salts cannot be preserved without efflorescing or some liquid kept in tubes gives rise to explosions. The pressure relations should then be examined. The compound may be decomposed by light of certain wave length, but stable under other conditions. The study of the rotation of a ray of light passing through the substance when it is maintained in a magnetic field may give him a clew as to some of its other properties. All the powers which he can command to produce variations, or hold conditions constant if he so desires it, must be at his command. The workshop holds now more tools,

all of which he should know how to handle. All chemical work is embodied in the work of variation, which, to produce the best results, must be performed very intelligently. If, knowing his tools and his material, he can foresee the results of his labors, he is fast reaching the goal of the chemist's ambition.

This intimate knowledge of the working value of these various implements which he will use requires the study of physics and of chemistry. If he did not know the values, he would not be able to reproduce or control the methods with which he works. The determination of values is therefore one of the problems that will confront him daily. The accuracy, importance, method, and theory of measurements must be thoroughly understood, before a real grasp of the value of work can be obtained. For much of this work, physics must be appealed to. Wherever the composition of matter is concerned, however, the chemist is concerned.

His training in his own subject should be such, therefore, as will enable him to be master of this field. The principles of variation in the occurrence, composition, formation and reaction of bodies should be familiar to him. If all teachers of chemistry were trained merely in some especial line of work such as agricultural, analytical, pharmaceutical, etc., chemistry, what would be the result if at the same time they were not given a broad training in the other divisions of the science? Would the object of chemistry appear the same to an organic chemist, with his study of the constitution of bodies and class reactions, as to that analyst whose main motive is the detection of the kinds and amounts of bodies present in a mixture? If, in addition to a broad training in the various branches, there is added a special course of study on problems where the application of principles is required, the student should know well the underlying principles of his subject.

But physics is not alone in being closely related to chemistry. The fact that relations between variables can be found, shows that an intimate relation between chemistry and mathematics may be established, although it may be and is the case that the factors have not always been recognized, differentiated, and valuated. Suppose that the problem is to determine the general relation between pressure, volume and temperature of a gas. First, one might keep all other variables (such as gravity, light, magnetic field,

etc., constant and find how the volume varies with the temperature; then, keeping all other variables constant, find how the volume varies with the pressure. By the aid of mathematics, it is now possible to combine these two relations into a general one which is applicable to all gases after one has inserted into the expression specific constants which depend on the nature of the gas. This equation is

$$(p+\frac{a}{v^2})+(v-b)=RT.$$

where a and b are the specific constants.

Many other such mathematical relations have been discovered and have found immediate application. Of course, these are *exact* only in so far as the initial assumptions are exact and the mathematical deduction free from error. The objects and methods of mathematical chemistry are too valuable to be ignored by any one who is desirous of fixing the accuracy of the so-called laws, or of testing theories. It is essential to study the basis underlying these as well as the exact laws discovered experimentally—e. g., combining proportions, definite and multiple proportions, combination by volume, etc.

In its applications, chemistry bears directly on all the other natural sciences. While it is always desirable and necessary to show the inter-relationships, it must be observed that these sciences have not contributed so much to put chemistry on the more rational and scientific basis as have physics and mathematics. The prospects for the future in these sciences cannot be gauged by the results of the past, since new plans and methods are continually being developed here also. If it were possible, every teacher should be trained and interested in the progress of all these related sciences; but, failing that, he should attempt at least to obtain a knowledge as to their aims, methods, results, and possibilities. The progress made in the past by a study of borderland subjects is but an earnest of what the future will repay its students.

But in what particular way will all this scientific training make the chemist better fitted for his work? He will understand more clearly the basis underlying chemistry, where is to be found exact-

ness or inexactness, which theories are sound and which based on insufficient evidence. He will recognize that all stages are not of equal rank in the teaching of chemistry and that at times one single fact may be of such fundamental importance as to outweigh hosts of other facts. He will learn how to perform experiments scientifically, recognizing their aim, devising the method, and explaining the results. Finally, he will have recognized that the methods of chemistry are, or ought to be, the methods of an exact science and that with proper training therein a man may attain the highest type of a scientific education.

The actual problems of the laboratory are many. The teacher must be artist and artisan—a rare combination. There are too many of the artisan class, those who try to raise all their structures on the one model set before them, whether it be their own or that of some educational institution. Such do not necessarily become the trainers of thinking students. The latter have not interrogation points at the end of many of their remarks to the teacher. Any leader of men, whether behind the desk or the writing table, who fails to leave any stray ends for his hearers to think about is, in a most important part of his work, a failure.

How can success be measured? It cannot be done. After recitation or lecture, none feels like congratulating himself—the number of mistakes or errors is too apparent. Illustrative experiments, more careful methods of presentation, more salient methods of attack present themselves continually. The chemist who studies variations must not forget that presentation is one of the least controllable of variables—the one, in fact, over which he can never get complete control and which therefore should call out all his best energies.

If this summary of the overlooked requisites in a chemical training arouses the interest of any so that he examines the subject in greater detail, the writer will feel well repaid.

THE PLACE OF PHYSIOGRAPHY IN THE HIGH-SCHOOL COURSE.

By Edw. G. Howe.

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There is no more profitable query for a teacher, than, in all honesty, to ask, "What is the desirable end of progress?"

Given, a group of children, with certain attainments and environment, what is the ideal for *them*?.

This question is worthy of the most careful consideration.

Once clearly discerned (even though in an imperfect manner), and the whole future of school or class will be benefited through distinctness of aim and problems of overcoming existing limitations in material equipment and teaching force will be greatly simplified.

This "progress," to be real, must rest upon a proper sequence of subjects.

Curiosity and the aesthetic sense have begun the child's training long before he enters the school room.

Birds, flowers, pebbles, the sunsets, the moon, leaves and the bright fruits of autumn are among the things which have held his interest, led to much unconscious experimentation and opened up many queries.

Even the child of the city has the parks, markets and shop-windows to interest him; and, in both cases, substantial progress has been made.

"The desirable end" would plainly seem to be the fostering and extending of these interests. To put new tools and methods in his hands, as they become strong enough to use them, and extend his horizon until it includes not only what is, but what has been; the *whole* as well as the parts.

In such comprehensive view, not only will the separate details be recognized, but the all-important knowledge of *their relations to each other* will be added.

Now, the fact is, that less and less has this relation of one thing to another been given due regard.

Knowledge has extended to such a degree that specialization

is becoming a serious peril; the results, in many cases, approaching that of astronomy with the law of gravitation left out.

We are so ardent and earnest in pursuit of the one subject in hand as to be in danger of forgetting that, by no possibility, can we know all about one thing until we have viewed it from all sides and in all its relationships.

That a reaction has already set in against this specializing tendency is witnessed by such signs as the growing use of the word "ecology," the character of the laboratory work outlined in texts and the revival of interest in physical geography (or physiography, as the new name is).

One remedy for this lack of correlation might well be to choose some central subjects ("Man," Pope would say), and *master* it; following out its relationships so thoroughly in all their ramifications as to know much of many things while learning all about one.

How feasible such a plan would be is known to the teacher who has given an enthusiastic class the rein and aided them in their study of side issues.

Few of us, however, are so situated as to follow such a plan to its conclusion, and, for the present at least, we must (confining ourselves now to the sciences) take our physiography, botany, zoölogy, chemistry and physics as separate subjects; each of which would greatly profit by coming after the others and having the advantage of their illumination.

As this cannot be, is there no other way by which these subjects can be more completely correlated and the inspiration gained from a broad and comprehensive view of each as parts of a mighty whole?

Before answering this question, it will be well to consider what has been *omitted* in these five common subjects of our high schools; or, if not wholly omitted, still so briefly touched upon as to need more attention.

Briefly enumerated, these are, the atmosphere and its movements, the ocean and its currents, the distribution of heat and moisture, minerals, rocks, soils, land formation and sculpture, the controlling factors in plant and animal distribution and the relation of all of these to man.

Note in passing that this list includes almost the *entire* inorganic basis for biologic life and activity!

Most of these are topics beyond the successful grasp of children in the grades, and for their apprehension require some knowledge of several of the sciences.

Now, in answer, geology will at once suggest itself as competent to supply this lack; but consideration will show its failure in several important essentials, among which are the subordination of the biological element and almost total absence of the human.

Repeated experience in the past has, however, shown that physiography is well suited for this.

In practice, the various sciences were given about the usual degree of attention; each one being vigorously pushed to a tentative conclusion; and then, to supply omissions, revive and freshen past acquirements and at the same time gain a fresh and inspiring new view of the whole, books like Guyot or Maury were made the basis of broad and thoughtful study.

The results were such as to commend the plan to anyone feeling a similar need.

MOISSAN'S WORK WITH THE ELECTRIC FURNACE.

BY FELIX LENGFELD.

The young student who goes into a chemical library and sees the hundreds of volumes that contain accounts of experiments performed by thousands of chemists living and dead, is apt to feel that nothing more can be done along simple lines, that future work must be upon very complex substances or very rare elements. That same feeling existed a hundred years ago and probably the chemist of the twenty-first century will envy us our virgin field.

In 1800, Crell, translating an article of Proust on copper salts, takes occasion to point out that young chemists should take courage when they see what Proust has done with an old subject, and it behooves every chemist to study carefully Moissan's work to

see the prizes that await the careful experimenter. When Moissan had isolated fluorine, after it had eluded other chemists for a century, it seemed to him that the well-known crystallizing power of fluorides might be used to crystallize carbon as diamond. Experiments in that direction failed. Moissan thereupon studied the occurrence of the diamond in nature and concluded that it was formed by the crystallization of carbon under pressure. This could be brought about in the laboratory by dissolving carbon in molten iron and cooling the outside rapidly. Cast iron expands in solidifying and therefore if a crust is once formed and does not crack, the pressure must increase as we approach the center. Carbon is more soluble in hot than in cold iron, and therefore the greater the difference between the melting point of the iron and the temperature at which it is saturated with carbon, the greater the quantity of carbon that separates in solidifying, and the greater the probability of obtaining diamonds. Something hotter than the oxyhydrogen flame was required, and the electric furnace was invented. Its simplicity challenges our admiration. Two blocks of lime or limestone are hollowed out so that a crucible can be placed in one cavity, the other being arched so as to reflect the heat downward. Openings are cut lengthwise to admit the carbons of the arc and the furnace is complete. In some, openings are cut horizontally at right angles to the arc carbons, so that carbon tubes may be inserted and reactions tried protecting the substance from the vapors in the arc. The blocks vary in size, depending upon the current used. In the smallest the lower block is 10 cm. by 18 cm. by 15 cm., in the largest 20 cm. by 35 cm. by 30 cm., the first figure giving the height. The covers are from 8 cm. to 15 cm. high. The carbons vary from 1 to 5 cm. in diameter and the crucibles from 4 cm. in height by 3 cm. in diameter (exterior) to 10 cm. by 9 cm. The crucibles are of graphite, but as this reduces lime they are always separated from the block by magnesia. A single experiment rarely lasts over ten minutes. With large currents the lime melts and even boils, and if the experiment be prolonged there is danger that the molten lime will cement the cover to the lower block. The substances to be heated are placed below the arc and the characteristic of the furnace is

that the arc is used merely as a source of heat and that there is no electric action upon the chemicals. The temperature of the furnace has been estimated at about 3500° and there is little doubt that the boiling point of carbon has been reached, so that it is not likely that higher temperatures will be obtained with larger currents unless means be found for working under pressure. Currents of 50 volts and 35 to 1000 amperes are used. Currents of over 1000 amperes are rarely used, as the disadvantages more than counterbalance the gain. The ordinary precautions in handling large currents and intense lights must be taken, dark glasses, for instance, being absolutely essential. As the electrodes do not fit into the furnace tightly, much heat escapes through the space between carbon and lime, but, on the other hand, the outside of the furnace remains cold and one may place the bare arm on the top of the furnace though the temperature but a few inches off is almost double that of the oxyhydrogen flame, and chalk, silica, manganese boil like water in a kettle.

A mixture of sugar charcoal and iron is heated in the electric furnace and then plunged into water. There is very energetic action, great quantities of oxygen and hydrogen being formed by the dissociation of the water, but there is no explosion. When the mass is cold the iron is dissolved in boiling hydrochloric acid. The residue consists of three varieties of carbon, and other impurities. It is treated with aqua regia, then with boiling sulphuric acid and hydrofluoric acid, then put into sulphuric acid at 200° and potassium nitrate slowly added. The amorphous carbon and most of the impurities are thus destroyed. The graphite is oxidized by the mixture of nitric acid and potassium chlorate. The small residue is again treated with boiling hydrofluoric acid, then with sulphuric acid, washed and dried, and then consists of small diamonds, some black and some transparent. The latter are denser and may be separated from the others by throwing all into bromoform, collecting those that sink and repeating with methylene iodide. The diamonds thus formed resemble most of the varieties of natural diamonds. Like natural diamonds they differ in hardness, color and luster. Though small, the largest being less than a millimeter in length, they are true diamonds. The scientific

problem is solved, but it will probably be many years before large artificial diamonds compete with the natural gem.

The reproduction of the diamond is but a small part of the work done with the electric furnace. At 3500°, carbon reduces most metallic oxides and it is thus possible to make in a few minutes masses of chromium, molybdenum, uranium, ziconium, titanium, etc. Metals that could be obtained only in small quantity and in fine powder with great labor can be made in masses of almost any size and their properties studied. At these high temperatures many metals combine with carbon, forming the interesting substances known as carbides. Some of these, as the carbides of calcium, barium, lithium, give, with water, acetylene; others like aluminium and beryllium carbides give methane; still others give mixtures of gaseous, or even of gaseous, liquid and solid hydrocarbons, and point to the inorganic origin of some petroleums. The carbide of silicon is so hard that it is used instead of emery under the name carborundum. Not alone carbides but silicides, borides, nitrides may be easily formed and many of them have been studied. Many minerals have been reproduced, many more will be, and we can feel certain that the electric furnace reserves many surprises for us, for the chemistry of high temperatures is still in its infancy.

THE STUDY OF BACTERIA IN THE PUBLIC SCHOOLS.

BY JAMES E. PEABODY.
Instructor in Biology, Peter Cooper High School, New York.

(*Concluded from page 306.*)

The practical applications of the subject were brought out in discussion of a list of questions from which the following are selected:

1. From all your experiments state—
   a. What conditions seem to favor the growth of bacteria?
   b. What conditions seem to hinder the growth of bacteria?

2. Why are fruits cooked before canning?
3. Why should fruit jars be filled completely before screwing on the cover?
4. Why is grass dried before putting it in the barn?
5. Why are milk, meat, etc., put in the refrigerator in summer time?
6. Why should the prohibition against spitting in public places be rigidly enforced?
7. Why should sweeping be done as far as possible without raising a dust?
8. Why are hard wood floors more healthful than carpets?
9. Why should the teeth be brushed often?
10. Why should the refuse be removed from the streets every morning early, especially in summer time?
11. Why should sink drains be carefully inspected?
12. Why should wounds be carefully cleansed and dressed at once?
13. Why are typhoid fever, diphtheria, and other infectious diseases often best treated in hospitals?

The tables of the New York Board of Health give figures and charts which serve to clinch the arguments in favor of good city housekeeping. The pupils copied into their note-books the following figures giving the annual death-rate per thousand of the population in New York City, 1886 to 1896 inclusive:

1886, 25.99	1891, 26.31
1887, 26.32	1892, 25.95
1888, 26.39	1893, 25.30
1889, 25.32	1894, 22.76
1890, 24.87	1895, 23.11

1896, 21.52 (first part of year).

There was little need to suggest that the sudden decrease in death-rate in 1894 and in succeeding years was doubtless due in no small measure to the efficiency of the Street Cleaning Department organized and directed by the late Colonel Waring.

After reading Dr. Prudden's books, and after class-room discussions, each pupil was asked to outline at home the arguments in favor of and against the bacteria. The case is stated thus in one of the papers:

Benefits of Bacteria to Mankind. They construct food-stuffs for plants out of the nitrogen gas and the solutions absorbed from the soil.

They ripen the cream before churning and thus form butter.

They give flavor to butter.

They are an absolute necessity in making cheese.

In making vinegar from cider, yeast and bacteria work together.

Bacteria perform a very necessary work in the process of "retting" flax in the linen industry, without which we would not have our fine linen and delicate laces.

Bacteria play a prominent part in the curing of tobacco.

Sprouting of seeds is promoted by bacteria.

Streams and lakes are cleared by bacteria.

They decompose dead animals into the dust from whence they came.

The Ways Bacteria Prove to be "Man's Invisible Foes." Bacteria cause the diseases, consumption, typhoid fever, scarlet fever, pneumonia, leprosy, lockjaw, influenza, cholera.

They cause blood poisoning.

They destroy foods.

The primary aim of these eight lessons in bacteriology, as already stated, was a practical one, namely, to present to the boys and girls of our city a most telling argument for cleanliness in the care of the home and in the care of the city. The colored charts portraying the cases of consumption in the region of Mott street and of diphtheria in the Tenth and Twelfth wards will not soon be forgotten. Hence the New York of tomorrow will doubtless number among its citizens at least a few more staunch supporters of an efficient Board of Health; a few more homes will probably be free from the danger of disease contagion, and a few more house-wives will exercise greater care to secure abundance of light and of fresh air in their homes and to select and prepare nutritious foods.

The treatment of the subject, however, was not allowed to leave in the minds of the pupils the lasting impression that we have discovered in bacteria an omnipresent and well-nigh omnipotent enemy. They were led to see that consumption, cholera, typhoid, and all the other diseases charged to these micro-organisms are due to the ignorance or carelessness of man, and that

these diseases can be prevented. On the other hand, they learned that the bacteria are toiling incessantly to clear our earth from the debris of decay, and to prepare the soil and the air for the growth of the higher plants. Thus this study becomes a part of the great study of biology, and in this fact lies the deeper interest of the subject. In the hay infusion all the functions of living nature are in full operation. There one may study assimilation, oxidation, respiration, excretion, the life and death struggle for food, reproduction, and even something akin to sensation; for who of us, after an hour at the microscope, watching the varying movements in this world of micro-organisms, is prepared to deny absolutely all sentient impressions even among bacteria? Biological study of this sort should not only result in more healthy bodies for our pupils and a more healthful community, but it should contribute largely to broaden and deepen the mental life of the student.—*Journal of Applied Microscopy.*

LIVING ORGANISMS IN THE STEREOPTICON.*

By W. Pfeffer.

The stereopticon with microscope attachment is little used for the demonstration of living organisms and vital processes in the class room, although its value is apparent, especially for inexperienced students who do not understand adjusting the microscope. A suggestive paper by Dr. W. Pfeffer, of the University of Leipsic, published in the *Jahrbücher für wissenschaftliche Botanik* (Bd. xxxv. h. 40) describes a series of microscopic and macroscopic demonstrations which he gives in his own lecture room.

Swarming movements are interesting, but on account of the difficulty of focussing and of keeping such rapidly moving bodies in the field, as well as not knowing what to look for, they are

*A condensed translation of Prof. Pfeffer's paper by Edith M. Brace, *Rochester, N. Y.*

not easily observed by young students without more personal supervision than is possible in a large class, but by placing a drop of water containing swarm-cells under the microscope of the stereopticon, they may be shown to a large number of students at once.

Pandorina morum is especially suitable for this on account of its large size, and the continuation of its movements for from fifteen minutes to half an hour. Some kinds of chlamidomonas, as well as Englena viridis, may also be used, or swarm-spores of Vaucheria, but they are not so good. *Paramecium aurelia* is another favorable organism that is very easily obtained. It is free-moving and irritable, showing a negative reaction to the rays of the electric lantern, although it is not clear whether this is due to the light or the heat. Galvanotaxis may be shown by passing an electric current through the water. The paramecia swim in all directions until the current is closed, when they immediately crowd around the cathode, while if the current is reversed they will swim across to the new cathode, showing a definite reaction, due to some inherent quality, for dead paramecia do not react in this way. *Pandorina morum* may be used for the same demonstration, but it moves more slowly and reacts in the opposite way, collecting at the anode instead of the cathode. An objective of low power, with large field, is preferable for this demonstration.

Paramecia and other colorless infusoria are shown with great distinctness by the stereopticon, or they may be stained with an .001-.005 per cent. solution of methylen blue, which is collected in masses in the contractile vacuole.

Quantities of paramecia should be available. They may be obtained from stagnant ponds, or from infusions made by leaving hay in water from four to eight days. They are found in greater numbers on the sunny side of the aquarium.

A bit of decaying matter placed on the slide just before the demonstration will attract them and show their tendency to heap themselves up around such material, but if left for a few moments they will all become scattered on account of the repelling action of the acid which they excrete.

Euglena viridis is also a good subject, and only after considerable exposure to the light begins to round off and form the resting stage, the observation of which is of still further interest. The streaming of protoplasm is not so easily demonstrated, but the rotation of starch grains may be shown with water-immersion objective 1.7 mm. or oil-immersion 2 mm., with ocular 2* or 4, projecting to a distance of 4 m. When thrown on a screen 80 to 100 cm. distant, they were as clearly shown as by microscopic examination.

Plasmodia of Myxomycetis are irritable to light, but may be shown in the steropticon with a weak current. The moving motion of oscillaria may be very beautifully shown by the stereopticon, but the filaments must be freshly mounted, for the movements gradually become weak after they have been placed upon the slide.

Many processes, such as alcoholic fermentation and intercellular permeability, are easily shown, as well as macroscopic objects. Contractile stamens of *Cynarea jacea* or *C. scolymus* were shown by placing the flower in water and removing the top of it to expose the stamens, which throw out a mass of pollen when touched. The leaves of Oxalis slowly droop if the plant is repeatedly shaken. A small specimen of *Mimosa pudica* may be placed before the stereopticon and all its reactions to stimuli shown. The growth of the root of a seedling may be shown by placing it in a jar of water surrounded by warm water. This requires high magnification to increase the apparent rate of growth.

For these demonstrations, the large projection apparatus of Zeiss was used, and the self-regulating lamp of Schuchert & Co., with electric current of about 30 amperes, as 60-70 amperes can hardly be used, the specimens being killed by the heat with a current of 30-50 amperes, unless special precautions are taken. To guard against this, the light from the electric lantern is passed through a glass cell 200 mm. thick, filled with water, which absorbs heat nearly as well as the saturated solution of alum commonly used.

Dr. Pfeffer also used a cell about 40 mm. thick filled with an

almost saturated solution of iron sulphate. This absorbs some of the visible rays and transmits a greenish light, which, however, is strong enough to project a magnification of 4,000 to 8,000 diameters. The water cell was surrounded with a zinc case in which ice was packed to further cool the apparatus. The translator has used a cell of about 150 mm. thickness, filled with a saturated solution of alum water, which was sufficient for demonstrations lasting not more than forty-five minutes, after which the cell was cooled under the faucet before the next demonstration.

DYNAMIC MEASUREMENT OF FORCE.*

By N. H. Williams.

Instructor in Physics, Shortridge High School, Indianapolis.

Although Newton's second law of motion may be axiomatic to the scientific mind, there can be no doubt that its application to the measurement of force is a problem that the student of elementary physics usually finds troublesome. Illustrations which are perfectly clear to some, seem to lie beyond the experience of others and usually fail to appeal to a majority. We often resort to experiment to clear up difficult points, and so it would seem in this case, that if the subject could be illustrated by some simple apparatus, its difficulties might be diminished. The student's ideas are vague and he needs something tangible upon which he can fix his thought.

Newton's second law of motion gives us one proportionality and another is even more obvious:—Momentum varies as Force, *i. e.*, $M V \propto T$; and Momentum varies as Time, *i. e.*, $M V \propto T$. If one quantity varies as two others jointly, it varies as their product, hence $M V \propto F T$ or $F \propto \frac{M V}{T}$ This may be

*Read before the Physics Conference of the Michigan Schoolmasters' Club, March 30, 1901.

written in the form of an equation, $F = \frac{MV}{T}$, provided we choose our units to fit the equation.

We are given our choice among three definitions of a unit of force. *First.* A unit of force is that force which will produce unit change of momentum per unit of time. *Second.* A unit of force is that force which, acting upon unit mass, will produce unit acceleration. *Third.* A unit of force is that force which acting for a unit of time upon a unit mass will produce unit change of velocity.

Suppose we choose the second definition. In order to illustrate this, it is evident that we must have a known mass acted upon by a known force and that we must be able to measure the acceleration. The product of the mass by the acceleration should equal the applied force.

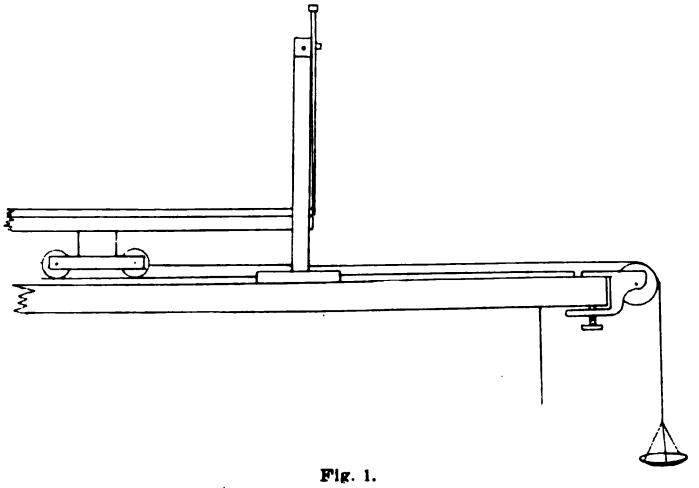


Fig. 1.

The mass consists of a car (Fig. 1) carrying a heavy wooden rod about a meter long. A thread fastened to the car passes over a pulley at the edge of the table and carries a scale-pan at its other end. This pan and the weights in it must be considered as part of the mass moved. The car runs on a long piece of plate glass which lies upon the table. Before the weight is put into the pan the glass is adjusted by slightly raising one end till the

car, when started, will have a uniform motion. Then by Newton's first law no unbalanced force is acting upon it. When the weight is placed in the pan, the car will have uniformly accelerated motion, and it remains for us to measure the acceleration. A pendulum (Fig. 2) vibrating half-seconds is suspended over

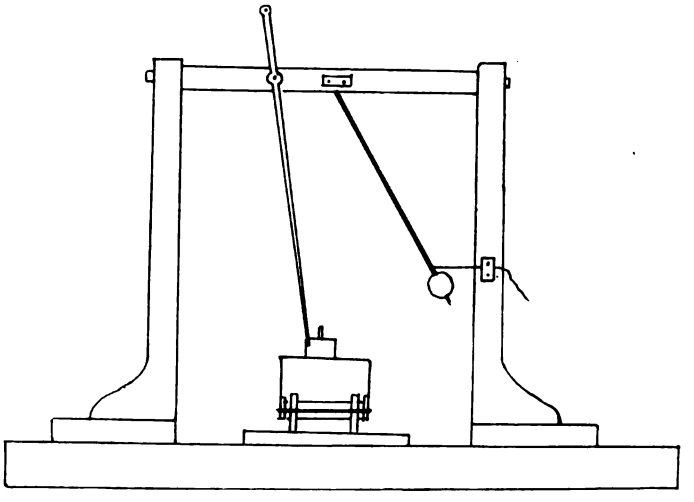


Fig. 2.

the car. A camel's-hair brush fastened to it is wet with ink and then the pendulum is drawn aside and fastened with a thread. The car is held in place by a long pointer, which is thrown aside by the pendulum at its first swing. When we burn the thread holding the pendulum, the car is released and the first mark across the wooden rod is made at the same time. The pendulum continues to swing as the car moves and thus the distances passed over in successive intervals of time are marked. The second, fourth and sixth marks are disregarded and the distances passed over in one, two, three, and four seconds respectively are recorded.

The total distance divided by the time gives the average velocity. Doubling this we get the final velocity, and the acceleration is the quotient of the final velocity by the number of seconds. We find the average acceleration and multiply it into

the mass moved. This result is in dynes. It is then reduced to grams and compared with the weight in the pan causing motion.

This experiment is fitted only for class-room work, as the adjustments are too delicate to permit of its being used as a laboratory experiment. The apparatus should be set up and adjusted before the class period during which it is used. When once adjusted, a few seconds only are required to get the results.

It will be observed that the apparatus will give the laws of accelerated motion, and might take the place of Atwood's machine. It also works admirably in experiments on "The Acceleration Test for Masses."

SOME RESULTS GIVEN BY THE APPARATUS.

Total Mass			1166 g.	
Force Applied			10 g	
t	S	Av. V.	Final V.	Acceleration
1	4.25	4.25	8.50	8.50
2	17.00	8.50	17.00	8.50
3	38.10	12.70	25.40	8.46
4	67.80	16.95	33.90	8.47

Average acceleration.....	8.482
Mass × Acceleration	9890
Force in grams	10.90
Percentage error	0.9%

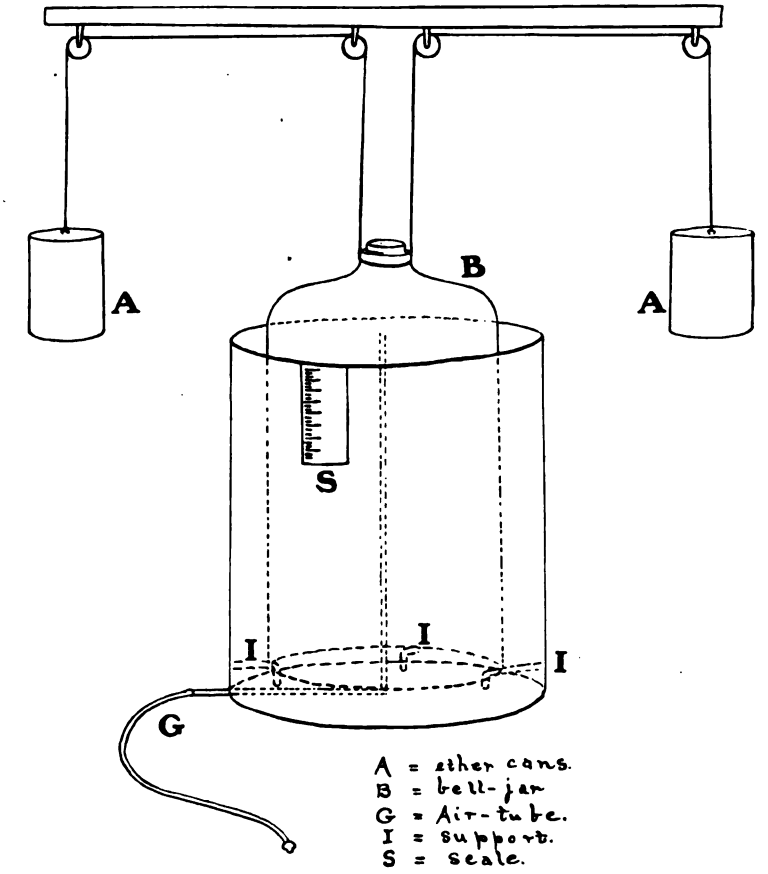
Total Mass			1171 g.	
Force Applied			15 g.	
t	S	Av. V.	Final V.	Acceleration
1	6.34	6.34	12.68	12.68
2	24.90	12.45	24.90	12.95
3	55.70	18.90	37.80	12.60

Average acceleration.....	12.58
Mass × Acceleration	1450
Force in grams.....	15.03
Percentage error	0.2%

A SPIROMETER AND ITS USE.

GRACE F. ELLIS.
Instructor in Biology, Central High School, Grand Rapids, Mich.

The spirometer in question was the result of many experiments and much trouble, but it could be duplicated or imitated without difficulty.



The can in which the bell-jar stands is of zinc 18 in. high and 10 in. in diameter. At the bottom are three supports on which the jar rests. The air tube enters on one side and is continued by rubber and glass tubing to nearly the top of the bell-jar. In this way it is not necessary to turn the stop cock in order to read the result.

At the top of the jar a piece of window glass is fastened with putty. Through this the graduations on the bell-jar can be read.

The jar is not graduated for the first 50 cu. in., as it is not necessary, and I fill the can so that the water is on a level with the first mark on the jar.

Graduations are for five cu. in. and the results are a close record of lung capacity.

At the top of the jar is a rubber stopper; removing this allows the jar to sink into the can after use.

The upward movement of the jar under air pressure is greatly facilitated by counterpoises. These are ether cans filled with red lead and attached to cords fastened at the neck of the jar and running over two pulleys on either side, which, in turn, are attached to a bar. The bar is rested across any two points at a suitable height, and the whole apparatus can be taken down and put away when not in use.

Both can and jar are larger than is absolutely necessary, as the former was made to accommodate a bell-jar also used to cover a compound microscope. Smaller apparatus would be more convenient and answer every requirement as well as this.

In connection with this apparatus the student is given a card calling for certain "vital statistics," which, when ascertained, are recorded in his laboratory note-book of physiology. He must get his exact weight before coming to class; height and chest measurements are taken at the laboratory. I use the following standards for tests of vital condition:

1. *Corpulence.* Relation of weight in pounds to height in feet. For a man 26 is the standard; below 23 he is abnormally thin. For a woman, 23 is the standard; below 21 is abnormally thin. In estimating the exact value of corpulence it should be taken in connection with vital capacity.

2. *Vital Capacity.* Normally, for a man of five ft. eight in., it is 230 cu. in. Relation between height and capacity for a man is 1 to 3, for a woman 1 to 26; *i. e.,* for each inch of height in a man there should be three cu. in. of lung capacity.

3. The thoracic perimeter should never be less than one-half the height of an individual. In man it is normally never less than 35 in.

Below is given a record from a student's notebook:

VITAL STATISTICS.

Name. James B. *Age.* 18 yrs. *Height.* 71 in. *Weight.* 145 lbs.

CHEST { *Inspiration.* 33½. / *Expiration.* 31. / *Average.* 32¼. } *Lung Capacity.* 265 cu. in.

Multiply your height in inches by 3 (if a boy), and by 2.6 (if a girl). *Result.* $71 \times 3 = 213$ cu. in.

My average is 3⅔ cu. in. to each inch of my height.

Chest Average = 32¼. *Half Height* = 35½.

$\frac{\textit{Weight in pounds}}{\textit{Height in feet}} = 24\frac{5}{71}$.

It is not necessary to suggest the various uses to which such a record may be put. There is no stronger argument for physical development.

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

(*Continued from page 319.*)

EXPERIMENT XI.

To find rate and period of the moon's diurnal motion.

(a) Stick a piece of lath, provided with a sight at the end, in the ground, and line in with the moon and this stick a second lath, pushing it into the ground firmly enough to hold it against

the wind. Indicate on the second lath the point where the line to the moon passes it. A half-hour or an hour later line in a third lath and mark it as you did the second. Note and record the time to the nearest minute in each case. Stretch strings from

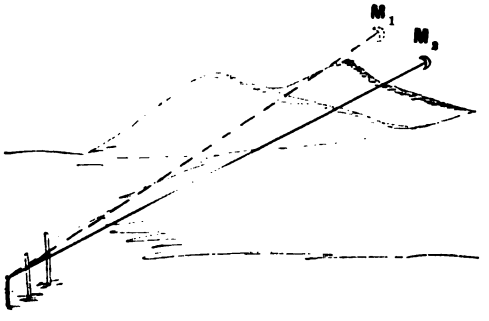


Fig. 14.

the first to both the second and third laths, and transfer the angle between the strings to paper, and measure it, or measure the angle directly. Finally, find how long it will require the moon to pass through 360 degrees at this same rate.

(b) It will be readily seen that this experiment may also be performed with the home-made plane table.

Experiment XII.

To measure angles between objects (stars, planets, etc.) in the sky.

(a) It will be readily seen how this may be done crudely with the aid of the data of Experiment II.

(b) A cross-staff or bar is recommended for this purpose also. This consists of a light stick some three feet long (a meter or yard stick), carrying a nail sight or perforated strip, at one end (the eye end), and provided with another stick which is held at right angles to the first, and sliding easily back and forth along the former. The cross-stick should be supplied with three or

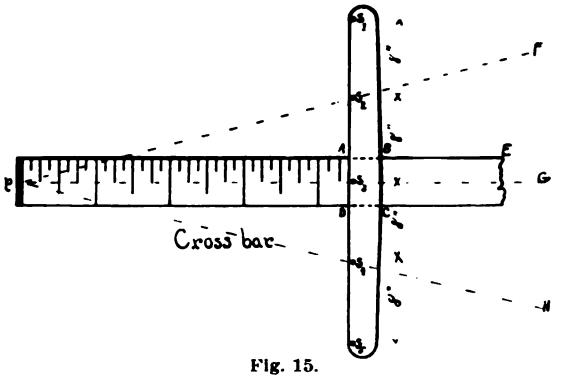


Fig. 15.

five sights, (S1, S2,....S5) one at either end, and a third in the middle. The cross-bar should be at least two feet long. The trigonometry class may graduate the long stick to correspond to various angles, and write the angles S1 p S3 and S2 p S3) beside the graduation marks. The sights must be large enough to be seen in poor light. The method of using this instrument is obvious. A faint light, placed behind the observer's head will illuminate the sights sufficiently.

(c.) The experiment may also be performed with the sextant. It is a good exercise for the home-made sextant referred to under Experiment VII (d).

Experiment XIII.

Locate stars on a spherical blackboard from Ephemeris values of Right Ascension and Declination.

(The Chicago Laboratory Supply and Scale Co. can furnish inexpensive globes for this purpose.)

(*To be continued.*)

Metrology.*

PARTIAL USE OF DECIMAL SYSTEM THIRTY-FIVE YEARS AFTER LEGALIZATION.

[CONTRIBUTED.]

The process of transition to the use of Federal money, inaugurated by resolutions of the Congress of the Confederation, July 6, 1785, and Aug. 8, 1786, was protracted through the time of our grandfathers, the generation following that which established the money. Kelly's *Universal Cambist,* whose preface is dated in 1821, thirty-five years after the original legislation, is a standard authority, having had official support. It said of the United States:

"Accounts are kept here in different ways, but chiefly in Dollars, which are divided into 10 Dimes, 100 Cents, or 1,000 Mills. This is called Federal Money, to distinguish it from the various currencies which were formerly the monies of the United States, and which are still partially retained in domestic traffic," etc.

The constitution of Massachusetts said then, and says now, in Chapter VI:

"III. In all cases where sums of money are mentioned in this constitution, the value thereof shall be computed in silver, at six shillings and eight pence per ounce," etc.

The United States Mint, though it began to coin money in 1793, did not strike many coins except cents, half-cents and half-dollars down to 1820; and coins of the several nations of western Europe continued in circulation. The Spanish original of our dollar was well known as the "piece of eight," meaning eight "bits" in the vernacular tongue of the United States, where the Spanish name is less familiar; one bit thus becomes 12½ cents obviously to us, but our grandfathers knew it as of the value expressed according to their long established custom in their different monetary reckonings. John Quincy Adams, Secretary of State, in his celebrated report on weights and measures, also dated in 1821, wrote as follows:

*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

* * * "now, when the recent coinage of dimes is alluded to in our public journals, if their name is mentioned, it is always with an explanatory definition to inform the reader that they are ten-cent pieces; and some of them which have found their way over the mountains, by the generous hospitality of the country, have been received for more than they were worth, and have passed for an eighth, instead of a tenth, part of a dollar. Even now, at the end of thirty years, ask a tradesman or shopkeeper, in any of our cities what is a dime or a mille, and the chances are four in five that he will not understand your question. But go to New York and offer in payment the Spanish coin, the unit of the Spanish piece of eight, and the shop or marketman will take it for a shilling. Carry it to Boston or Richmond, and you shall be told it is not a shilling but nine pence. Bring it to Philadelphia, Baltimore, or the city of Washington, and you shall find it recognized for an eleven-penny bit; and if you ask how that can be, you shall learn that, the dollar being of ninety pence, the eighth part of it is nearer to eleven than to any other number," etc.

This was characterized by Mr. Adams as absurd, and justly. Oh, yes—but—by the way, what is it that we are doing, A. D. 1901, thirty-five years after the inauguration by our fathers by the Act of Congress of July 28, 1866, of the change to metric weights and measures? Our rates of postage on foreign mail matter are by weights in grams, and we try to look them up in pocket diaries or other common places of reference and find them inaccurately stated by weights in ounces. We turn to the Revised Statutes of the United States, Section 3515, referring to our minor coins, and read:

"The weight of the piece of five cents shall be seventy-seven and sixteen-hundredths grain troy":

a circumlocution for five grams. We have had profile paper printed with metric subdivisions for its whole length and have measured it off in portions for sale by the yard. Imported paper in rolls of ten meters we have advertised as eleven-yard rolls. These few examples suffice out of many instances of misapplication of units of quantity in business and in publications.

We see the unreasonableness both of the Massachusetts constitution and of the adherence by our grandfathers, so long after they had established decimal reckoning, to their antiquated book-keeping, which occasioned great inconvenience from the incongruity of the two methods in use at the same time. When our grandchildren look back to 1901, what will they say of our now

hanging on to weights and measures that are out of date by consequence of the substitution of the metric units legalized thirty-five years ago?

Consider electricity, whose standards of measurement are fixed upon a metric basis by the law of July 12, 1894. The following is an extract from it:

> "The unit of power shall be the watt, which is equal to ten million units of power of the centimeter-gram-second system, and which is practically equivalent to the work done at the rate of one joule per second."

Several of the electrical units have become familiar to us through the enormously rapid development of the applications of electricity. This is the case especially with the kilowatt, a commercial unit which we meet with in almost every technical publication we take up; but it has not yet entirely displaced that anomalous old unit, the horse-power (as to which reference may be made to *Engineering*, vol. 63, pp. 245 and 325, for Feb. 19 and March 5, 1897).

Consider the matter of assaying and coinage, in which the metric system is established. It has been used in the Mint for years, and is used in published tables or schedules of coins. The United States subsidiary silver money weighs one gram per four cents, and thus metric weight is in everybody's pocket. The troy pound has dropped out of practical use. Nevertheless, the troy ounce, incongruous as it is with other weights and measures, still comes in our way sometimes (in other places besides the Massachusetts constitution).

Consider pharmacy and some other matters connected with chemistry. The *United States Pharmacopoeia*, the reference manual of the apothecary, is exclusively metric. The *Dispensatory*, the corresponding manual of the physician, has metric values throughout. The use of the metric system was introduced in the United States Marine Hospital service about a quarter of a century ago quite thoroughly, and in the army and navy more recently. In practice in civil life prescriptions are to a large and increasing extent written in metric terms; but the mysterious old "apothecaries'" weights and measures (which for sales of candy and popular wares are not used by apothecaries) continue to be

used in the prescriptions of some of the older physicians, who in the natural course of events are gradually passing off the stage. Meanwhile pharmacists have double sets of weights and measures, and employ clerks who understand both, with extra trouble, cost and risk of mistake. In the sale of high grade chemicals the metric system has been introduced. E. R. Squibb & Sons, of Brooklyn, have used it exclusively for nine years, and the Bausch & Lomb Optical Co., of Rochester, issues a sixty-page priced catalogue "G" of "Chemicals and Reagents" in metric terms, with a conspicuous notice at the top of each page, "Prices of Chemicals are by Metric, NOT Avoirdupois Weight." Much glassware and rubber stoppers are made to metric scale. As to chemical manufacturing, all the tanks in a factory built by the Merrimac Chemical Company, of Massachusetts, for their extensive sulphuric acid works, were made on metric dimensions, and the Pennsylvania Salt Manufacturing Company have built a large plant entirely upon metric dimensions. The great Solvay Process Company, of Syracuse, makes use of the metric system in every way possible in its works. Drawings to go outside of the works for construction, etc., are not made in the metric system. The company says it finds no disadvantages, and would be very glad if its entire work could be upon the metric system. That means that as long as people outside cling to ancient weights and measures, so that conformity with them is required of the Solvay Process Company, the company gets only part of the advantages naturally belonging to its system. Chemical analyses are expressed in parts per million, per hundred thousand or per thousand, corresponding to grams per cubic meter, per hektoliter or per liter. Grains per gallon are out of date. Nevertheless, in dealing with quantities and consumption of water there still lingers some use of the United States liquid gallon, a unit long ago abandoned in Great Britain and Canada, distinguished for its lack of connection with other measures or weights, and not ordinarily used in the reading of water meters.

Consider geodesy and precise leveling. The metric measure has been very extensively used in precise leveling or other work of the United States Coast and Geodetic Survey, the United States Geological Survey, the United States Lake Survey, and the sur-

veys under the Mississippi River Commission. Among other literature from which evidence may be obtained about this, and about working in old measures incongruous with metric, there is an article and discussion on "Precise Spirit Leveling," occupying pp. 1-206 of Vol. 45 of the Transactions of the American Society of Civil Engineers, June, 1901.

Bulletin No. 26 of the United States Coast and Geodetic Survey, dated April 5, 1893, contained an announcement signed by T. C. Mendenhall, Superintendent of Standard Weights and Measures, and approved by John G. Carlisle, Secretary of the Treasury, from which the following is an extract:

* * * "the Office of Weights and Measures, with the approval of the Secretary of the Treasury, will in the future regard the international prototype meter and kilogram as fundamental standards, and the customary units, the yard and the pound, will be derived therefrom in accordance with the Act of July 28, 1866. Indeed, this course has been practically forced upon this Office for several years," etc.

The Treasury Department is the department to which are attached the Mint, the Marine Hospital Service and the Coast and Geodetic Survey, in all three of which, as above stated, the metric system has been in practical use for years. Incongruity is found, however, in the fact that the Treasury Department continues the use of old weights and measures in other branches of its work; for example, in its Bureau of Statistics, largely occupied with foreign trade (whereas metric units have been introduced to some extent in the Bureau of Foreign Commerce of the State Department and in the section of Foreign Markets of the Agricultural Department); and, for another example, in the Customs Service, where there will be special gain in the substitution of the international system, and where its substitution has been repeatedly urged, officially and unofficially.

Consider manufactures. The April, 1900, report of the American Railway Association's Committee on the Metric System enumerated among manufactures in which the metric system has been introduced watches, injectors, refrigerating apparatus, screw-cutting lathes, scales, drills, gauges, astronomical and physical instruments, measuring implements and draughtsman's supplies. A very large number of manufacturers have had some call for the application of metric measurement for goods for

export, if only on a small order; and goods of widely diverse character are among the metric manufactures. We have exported to metric countries a great deal of ordnance and machinery for manufacturing ordnance, and rapid-firing guns have been designated by their caliber in millimeters. The Baldwin Locomotive Works' illustrated catalogue of narrow-gauge locomotives has printed on its title page, "Adapted Especially to Gauges of 3 Feet 6 Inches or One Metre," and on each of the sixteen pages (108-38), on which are tabulated various types of locomotives, has printed conspicuously, "Gauge, 3 Feet 6 Inches, or One Metre." The Library Bureau, of Boston, has cards and cases made of exact metric dimensions. In the *Electrical Review* (New York) for June 22, 1901, Geo. H. Draper says:

"There is no first-class shop in America that will not undertake to build machinery according to metric measurements, and many of them are at the present time compelled to build stock forms of machinery in measurements of this system in order to be able to compete for trade in foreign countries where the specifications are given in round metric terms."

NOTES.

A Decimal Association. At the August meeting of the American Association for the Advancement of Science, held in Denver, Colo., Jesse Pawling, Jr., of the Central High School, Philadelphia, read an instructive paper on the metric system, advocating the formation of a Decimal Association, similar to the one in England, for the purpose of promoting metric reform and urging the passage of a metric bill by Congress.

The Metric System and International Commerce. Under this title Cassier's for September contains an interesting paper by J. H. Gore, secretary of the American Metrological Society. The one great question now paramount in the minds of the commercial world, he says, is how to extend trade—how to remove the barriers that stand in the way of natural tendencies and artificial stimuli. He quotes Mr. Furbish, formerly director of the Bureau of American Republics, who says: "The failure of the United States Government to adopt the metric system is one of the most inexplicable instances of false conservatism in the history of the country. We send consular representatives to every quarter of our globe for the express purpose of making possible an extension of our foreign commerce, and then busy ourselves in an attempt to make such foreign commerce impossible, and retain a system of weights and measures which adds to our own difficulties and makes us mere barbarians to the more

progressive nations." He mentions that letters from eighteen important consulates to the British House of Commons, in every case state that the adoption of the metric system by Great Britain would greatly promote her commerce. "There can be no possible doubt of these facts, and the United States, in its commerce, is today suffering from the same cause. We are out of touch commercially with all the nations of the world except Russia, with which our commerce is small, and England, with which our trade is not growing."

Evolution of Standards of Measurement. In the September *Cassier,* John A. Brashear writes of the development of linear standards and machines for making exact divisions. The early standard in Biblical writings and in Egypt, Babylonia, Persia, Greece and all eastern countries was the cubit. Medieval metrology is omitted for "a period of more than a thousand years over which the connection of units of measure is very uncertain." The Belgic foot was probably carried over to Great Britain in the tenth century, and was 13.22 of our present inches. The legal foot of 12 inches was enforced by law in 950, at which time Henry I. made it one-third of a yard, the later standard being half the distance from the finger tips of that king's outstretched arms.

In 1324 Edward II. created a new standard—the barley corn, 3 grains of which placed end to end were decreed to make an inch. From this time onward for 500 years the yard and ell had various values, until 1824, when George IV. gave a legal definition to the yard as marked on a certain bar made by Bird in 1760. This was known as the Imperial Standard Yard, and has ever since remained the standard of length in England.

The rise of the metric system is briefly described. Down to the beginning of the seventeenth century there were no instrument makers, but about the middle of that century astronomy demanded a higher grade of instruments. Whereas the earlier *circles* were all divided by hand, dividing engines are now employed with much greater precision, as in setting off *linear* measurements. Space is given to the names and work of inventors and users of these engines. Reference is made to the work of Michelson with the refractometer in measuring the length of light waves, which furnished a delicate subdivision of the meter.

The paper ends with a brief account of the invention since about 1860 of machines for making interchangeable parts and standard screw threads, in which latter, the author says, there has been a saving to the railways of the United States of hundreds of thousands if not millions of dollars. The fineness of such measurements is shown by the possibility of making all standard gauges accurate to within one-forty- or fifty-thousandth of an inch; while gratings by Rowland's engine can be made 120,000 to the inch so accurate that an error of one two-millionths of an inch is not found between adjacent lines. Such lines open great possibilities in spectrum analysis.

R. P. W.

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of great value.

CHEMICAL.

Aluminum Iodide may be very readily prepared by putting a mixture of equivalent proportions of aluminum foil and iodine with about three times its weight of carbon bisulphide in a glass stoppered vessel. The mixture is allowed to stand at the ordinary temperature. The iodide dissolves in the carbon bisulphide as soon as it forms, and in a couple of days the reaction is completed.

Jour. Prak. Chem. (2), LXIII, 110. G. GUSTAVSON.

Temperature of Ignition of Phosphorus.—A current of air or other gas was bubbled through melted phosphorus under water. The temperature was gradually raised and readings on a thermometer in the water taken at regular intervals. The ignition point was taken to be the temperature at which the temperature of the water began to rise rapidly. This was found to be 45.0 to 45.2 deg. in air or ogygen, or air mixed with an equal volume of carbon dioxide.

Rec. Trav. Chim. XIX, 401. F. H. EYDMANN.

Preparation of Anhydrous Calcium Chloride. Calcium chloride is a good drying agent only when it is quite free from water. Small quantities of the chloride may be rapidly and perfectly dried as follows: A lump of the chloride is grasped with tongs and held in a large blast lamp flame. It soon begins to melt and drops fall off. These may be caught on a sheet of metal placed under the lamp, and the flattened, solidified drops put in a tightly corked bottle without delay. Calcium chloride so prepared makes a very efficient drying agent, as it is perfectly anhydrous and presents a good deal of surface for its mass.

The Metallic Luster of Sodium or Potassium is hard to show to a class, as these metals oxidize so readily. By the following method, however, the metals can be obtained under conditions permitting of the preserving of their metallic luster indefinitely and of ready demonstration. A test tube is filled half full with paraffine which is melted in a bare flame, and heated until it is hot enough to begin to smoke. Pieces of sodium or potassium as large and as clean as possible are dropped into the hot paraffine. They are then well shaken in order to remove the coating of oxide and the tube laid in an almost horizontal position to cool. Oftentimes the metals form into balls which cannot be made to coalesce, but these flatten along the glass and exhibit the metallic luster as well as a continuous band of the metal.

Electrolytic Manufacture of Sodium.—In Fischer's process a mixture of 75 parts of potassium chloride and 59 parts of sodium chloride is electrolyzed in an electric furnace in a wide and shallow crucible provided with a middle partition not quite reaching the bottom. The horizontal electrodes pierce the sides of the crucible at opposite ends of a diameter perpendicular to the partition. The anode is a solid carbon rod, and the cathode a metallic tube, whose axis is level with the surface of the fused mixture in the crucible. The sodium formed contains only about one per cent of potassium and is removed through this tubular cathode. The advantage of using two chlorides is that their mixture has a lower melting point than either of the chlorides alone, and the temperature can therefore be kept down, thereby preventing much loss of sodium by volatilization.—*Electrochemist and Metallurgist.*

Preparation of Ethylene.—"About 50 or 60 cc. of syrupy phosphoric acid of sp. gr. 1.75 are placed in a small Wurtz flask of about 180 cc. capacity. The flask is fitted with a cork carrying a thermometer and a dropping tube, the end of the latter being drawn out to a fine tube, and reaching to the bottom of the flask. Phosphoric acid of sp. gr. 1.75 boils at a temperature of about 160 deg. It is heated in the flask and allowed to boil for a few minutes until its temperature reaches 200 deg., when ethyl alcohol is allowed to enter drop by drop. Ethylene is immediately disengaged, and by maintaining the temperature between 200 and 220 deg. a continuous supply of the gas can be obtained even from so small an apparatus at the rate of 10 to 15 liters per hour. The gas should be conducted through a small Woulf's bottle (100 to 150 cc. capacity) standing in a vessel of ice, in which an aqueous liquid collects containing a small quantity of ether, undecomposed alcohol, and traces of an oily liquid. The gas which passes on is practically pure ethylene, and contains no trace of carbon dioxide, and of course not sulphur dioxide. It is absorbed completely by fuming sulphuric acid. There is no charring or separation of carbon in the reaction flask, for although the liquid assumes a brownish color, it remains perfectly clear. The mixture does not evince any tendency to 'froth up,' hence the operation may be carried out in small vessels. The process appears to be continuous, and so long as the supply of alcohol is maintained, the operation will go on without attention for apparently an indefinite period. In one experiment the action was allowed to continue for several hours a day for a whole week, during which time several hundred liters of ethylene had been generated by the same quantity, 50 cc., of phosphoric acid."

Jour. Chem. Soc., LXXIX, No. 916. G. S. NEWTH.

PHYSICAL.

The Largest Induction Motor in the world has a capacity of 1,000 horse power at 5,000 volts. It was made in Switzerland.

Ions in the Atmosphere. H. Ebert has found that the number of ions in the atmosphere is very much larger in clear, sunny weather than in air filled with dust or moisture, although the number is very small in either case. The free charges in one cubic meter amount to about one electrostatic unit, an amount that would be accounted for by the dissociation of the 10,000 billionth part of the oxygen. This amount of ionization is about the 100,000th part of that produced by feeble Roentgen rays.

Aluminum for Kundt's Experiment. Aluminum rods three-eighths to a half inch in diameter are superior to the brass rods commonly used in the determination of the velocity of sound by Kundt's method. The tone is not only more resonant but it is also more uniform and more easily started, there being none of the slipping of the rubbing cloth too often observed with brass. The tone is remarkably clear and musical and the comparative absence of overtones causes the nodes to be particularly well marked in the tube.

"What is Electricity?" was once asked of Thomas A. Edison. His reply was: "I don't know, for I am not an electrician. I am a mechanic who happens to know that under certain conditions and with certain guiding appliances the electric current will do certain things. I simply utilize the work of electricity just as an engineer will utilize the work-giving properties of live steam. He doesn't know exactly what steam is. He knows that if water is heated in a closed boiler and is made hot enough that what he calls steam operates his engine. If you tell him it is not the steam, but heat, that does the work, he cannot successfully prove that you are wrong. As a matter of fact, it is heat in the steam which gives steam its expansive properties. The steam, the vaporized water, is simply the vehicle which carries the heat to the point where the work is accomplished. Now, that is the way I look at electricity. The current, if it is a current, is a movement of something which I know will give me certain results under certain conditions. All I have to do is to meet the requirements and I will surely accomplish my planned results."

A New Storage Battery has recently been patented by Thomas A. Edison. Magnesium is used as the support upon which the zinc is deposited when the battery is reversed after discharging. Although mag-

nesium has a greater solution tension than zinc, there seems to be no local action between the metals. The zinc adheres very firmly to the magnesium even when the current density is quite considerable. The negative element consists of finely divided copper which is first moulded into form, then converted by heating into the black oxide, and finally reduced. In charging the copper is converted into the red oxide. The copper is supported in perforated receptacles attached to nickel or nickel-plated plates. The solution is a twenty per cent solution of sodium hydroxide in which zinc hydroxide is dissolved nearly to saturation. The charging is continued until about seventy-five per cent of the zinc in the solution is deposited on the magnesium. The battery has a voltage of 0.67 volt.

Reports of Meetings.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirty-first meeting of the Association was held in Salem, Mass., Saturday, November 16, 1901. The members of the Association were the guests of Mr. Charles E. Adams, teacher of Physics in the Salem Normal School. About twenty-five members were present. President Herbert J. Chase of the Danvers (Mass.) High School presided. After the customary routine business the following new members were elected: Mr. Arthur N. Burke, High School, Waltham, Mass.; Mr. Kirk W. Thompson, High School, Beverly, Mass.; Mr. Walter H. Buck, High School, Leominster, Mass.

In the absence of Mr. C. H. Andrews, chairman of the committee on apparatus, Mr. I. O. Palmer presented the following report: Attention is called to three pieces of apparatus. (1) A D'Arsonval Galvanometer. This galvanometer is compact and handsome. Like all galvanometers of this class it is independent of external magnetic fields and is nearly dead beat. The sensibility is about seventy-five megohms. As it is a mirror galvanometer, either a reading telescope or a sight and scale attachment is necessary. The price, including the sight and scale attachment, is about $14.50. For very accurate work it is recommended that a reading telescope be substituted for the sight and scale attachment. This galvanometer is serviceable when it is desired to put a high grade instrument into the hands of an ordinary pupil. (2) A Jolly Balance. This balance consists of two nickel plated telescoping tubes, mounted on

an iron tripod, with leveling screws. The inner tube can be adjusted up or down by a milled knob, and 50 cms. of its length is graduated in millimeters. A portion of the end of the outer tube is cut away and the edge is beveled. On this edge is cut a scale 9 mm. long, divided into 10 equal parts, thus forming a vernier which permits accurate reading to tenths of a millimeter and approximate ones to hundredths of a millimeter. The spiral spring is suspended from the crossarm of the inner tube. On the lower end of this spring is fastened an indicator, consisting of a narrow strip of aluminum having two crossarms, one above and the other below a glass tube through which the indicator passes. This arrangement permits a play of only 12 mm. of the spring up or down when objects are placed on or removed from the pans. In using this balance the indicator is first brought to zero by adjusting the tube which carries the spring and then reading the vernier. Any elongation of the spring is measured by raising the inner tube until the indicator is again at zero, and then reading the vernier. The difference between the two readings measures the elongation. This balance is very accurate.* (3) An Attachment for a Second's Pendulum. This attachment is intended to replace the customary mercury contact for indicating seconds. The device is attached to the laboratory clock. Details may be obtained by communicating with the Standard Electric Time Company, Waterbury, Conn.

Mr. J. C. Riley presented a brief report for the committee on current literature.

Mr. A. H. Berry read a review of Gilley's Principles of Physics, presenting in a compact form the features of this book and calling especial attention to its indispensable value to teachers.

The members then went into the laboratory, where Mr. Charles E. Adams gave an exhibition and explanation of original diagrams and devices for use in teaching physics. Among many striking, simple, and instructive things the following deserve mention: (1) Transference of energy by vibration was illustrated by starting a wave of water at one end of a long sink, and as the wave struck the other end water flew out. It was also shown by shaking a clothesline in the way the coiled wire is usually shaken, but in this case a bell, attached at the end of the clothesline, was rung by the wave. (2) A sinusoidal curve was drawn on the blackboard by holding a piece of chalk in the hand and letting it form the curve as one walked alongside the board. Another "wave device" was walking along by a sheet hung from the ceiling—the sheet assumes a wave shape like that produced in the air by walking through it. (3) The entire subject of refraction was shown to the whole class

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* The galvanometer and balance are made by the Chicago Laboratory Supply and Scale Company.

by one piece of apparatus consisting of a long tank (with glass sides), into which colored pieces of wood dipped. The tank was about six feet long, and when filled with water and supplied with the variously colored sticks it gave a vivid and convincing proof of refraction. (4) Telegraph and telephone diagrams made of colored paper and pasted on the wall showed how these subjects may be explained with ease. (5) A tabular statement of the difference between mass, volume, density, weight, and specific gravity illustrated in a concise form these confusing terms. (6) Diagrams illustrating the laws of falling and of rising bodies showed in a compact form the complete subject.

After lunch the members listened to an address on "The Life and Work of the Late Professor Henry A. Rowland," by Professor A. DeF. Palmer of Brown University, Providence, R. I. Professor Palmer was at one time a student and co-worker with Professor Rowland. The first part of the address was an interesting account of the early life and the personality of the distinguished scientist. Attention was called to the fact that his remarkable insight into scientific and mathematical subjects was shown early in his career. His notebooks made when a student and tutor are full of data which may in time furnish material for many important investigations. Mention was made of Professor Rowland's love for outdoor sports, especially hunting and sailing, and of his custom to spend Saturday afternoon in the pursuit of some agreeable pastime in the open air. His rapid manner of lecturing, his hatred of sham, his ardent love of truth, his willingness to acknowledge his own errors, his stupendous grasp of problems, his tireless labors, and marvelous results were all touched upon by the speaker. The second portion of the address was devoted to an exposition of the four important researches of Rowland, viz.: Magnetic permeability, electrical convection, mechanical equivalent of heat, concave gratings, and the solar spectrum. Each of these researches was explained by Professor Palmer by the aid of diagrams, formulas, or the original publications. A concave grating was shown, and also a portion of a large photograph of the solar spectrum made by a grating. Considerable time was devoted to a description of the engine by which the gratings were ruled, and to the method of photographing the solar spectrum, since it proved to be an intensely interesting subject to the members.

This address was followed by an exhibition of some lantern slides, showing the construction of the constant current transformers in use at the Salem (Mass.) electric light station. The views were explained by the Secretary, Mr. F. R. Hathaway. After a vote of thanks to Dr. H. P. Beckwith, Principal of the Salem Normal School, Mr. Adams, and Professor Palmer, the meeting adjourned and the members went to the electric light station to observe the operation of the transformers.

Reported by LYMAN C. NEWELL.

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS.

The twelfth meeting of the Asscciation was held in Boston, Mass., Saturday, November 23, 1901, at the Massachusetts Institute of Technology. There were about thirty members present. President R. P. Williams presided. Dr. H. G. Shaw of the Murdoch School, Winchendon, Mass., was elected secretary *pro tem.* The secretary's report of the previous meeting was adopted as printed—subject to corrections which might be made at the next meeting. Mr. Francis R. Hathaway, Salem, Mass., and Mr. F. Newton Black, Roxbury, Mass., were elected to associate membership—there being no vacancies on the active list. President Williams called attention felicitously to letters and a circular received from the Pacific Coast Association of Chemistry Teachers, and on a motion of Mr. Charles R. Allen the Secretary was directed to exchange publications with this and similar organizations, and to send all publications of the Association to prominent educators and the well known educational publications. The president likewise called attention to Benedict's Chemical Lecture Experiments (Macmillan), Newth's Chemical Lecture Experiments (Longmans, Green & Co.), and to Harcourt and Madan's Practical Chemistry (Clarendon Press). He also passed about for inspection a sample of the Atlas Tablets, a form of notebook adapted for laboratory notes in science. In the course of the meeting the president showed specimens of carborundum and artificial graphite obtained by him at the recent Pan-American Exposition.

Vice-President Albert C. Hale then addressed the Association on Pictet's method of obtaining oxygen gas on a large scale by means of liquid air. He stated very clearly the general principles of the liquefaction of gas, gave a brief account of Count Rumford and his connection with the Royal Institution at London, and referred, of course, to the preliminary work of Faraday and the later work of Dewar at that Institution. The principle on which Pictet's method is based is the well known one, viz., that liquid nitrogen boils at a lower temperature than liquid oxygen, and hence the nitrogen completely leaves a mixture of the two before the oxygen entirely evaporates. The speaker then gave a graphic account of some experiments which he saw Pictet perform, in which air was liquefied by forcing it by a bicycle pump through a tube immersed in liquid air contained in a Dewar bulb. With every stroke of the pump liquid air trickled down the immersed tube. Later experiments have shown that air around a tube of liquid air may itself be liquefied by exhausting the air from the inside of the tube of liquid air. By means of a diagram Dr. Hale showed the original process of Pictet for getting oxygen gas from liquid air. The details of this apparatus, as well as a statement of the process, may be found in the United States Patents Nos. 726,334 and 683,492. It is reported that the apparatus is able to produce 1,000,000 cubic feet of oxygen gas an hour at a cost of

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TILDEN FOUNDATIONS

one cent a cubic yard. The solid carbon dioxide which is incidentally produced is sold as a refrigerant and is said to yield a return sufficient to pay the operating expenses of the plant. The oxygen may be used, according to Pictet, to increase combustion at a decreased cost. No commercial use has yet been found for the nitrogen.

The general subject for discussion was "Chemical Experiments." Mr. James E. Downey of the Worcester (Mass.) Classical High School described the method used by his classes to determine the atomic weight and valence of zinc. The relation of zinc to hydrogen and to chlorine was found. From this experimentally-determined relation of zinc and chlorine, the formula of zinc chloride must be $ZnCl_2$ and not ZnCl nor $ZnCl_3$, since $ZnCl_2$ is the only formula which agrees with the experimental evidence—the molecular weight of zinc chloride having been previously told the pupils. Since $ZnCl_2$ is the correct formula, the valence of zinc is two. Mr. Edward F. Holden of the Charlestown (Mass.) High School explained by a diagram a successful method of preparing sulphur trioxide. The sulphur dioxide, prepared by burning half a gram of sulphur in a deflagrating spoon in a bottle (2 or more liters) of oxygen, is drawn by an aspirator through three U tubes containing beads moistened with concentrated sulphuric acid and then through a hard glass tube 5 mm. in diameter containing a pinch of platinized asbestos; the sulphur trioxide passes into a fourth U tube attached to the hard glass tube and standing in a freezing mixture of ice and salt. Care must be taken to have all joints tight, and to use enough drying tubes to obtain a perfectly dry gas, otherwise the product will be a mere cloud and not the "frosty" solid. Mr. Charles H. Noyes of the Nashua (N. H.) High School gave an interesting account of the detection of "lactone," an artificial coloring matter used to make milk look "creamy." Sulphuric acid added to milk containing "lactone" produces a persistent pink color. Miss Emma H. Parker of the Newton (Mass.) High School outlined the plan of finding the atomic weight of zinc used by her classes. The subject of atomic weights naturally arose from the performance of several quantitative experiments. The relation of zinc to hydrogen, chlorine, and oxygen was found; that to hydrogen as usually, that to chlorine by weighing the residue obtained by dissolving a known weight of zinc in hydrochloric acid, and that to oxygen by heating to constant weight the residue obtained by dissolving a known weight of zinc in nitric acid. A determination of the specific heat of zinc by the usual method found in a textbook in physics settled the number to be chosen as the atomic weight. Mr. Wilhelm Segerblom of Phillips Academy, Exeter, N. H., described in detail the plan used by him to determine the composition (qualitatively) of nitric acid. Each constituent was detected by a series of connected experiments involving previous knowledge and compelling the pupil to rely on judgment as well as on experimental evidence. Miss Delia M. Stickney of the English High School, Cambridge, Mass., stated

briefly her plan of teaching self-reliance. Two classes are in the laboratory at the same time. One is assisted, while the other is set a task but given no assistance whatever. The pupils deprived of help soon learn that if the work is to be done it must be done by themselves. Dr. H. G. Shaw gave an extended account of the work done by his classes in chemistry after they have had enough preliminary work to acquire skill in manipulation. The usual experiment in neutralization is modified. Instead of using solutions of unknown strength, the pupil is given a solution of sulphuric acid of known strength which he titrates against a solution of sodium hydroxide (prepared by himself), and from his own results computes the weight of sodium hydroxide necessary to neutralize one gram of sulphuric acid. The laws of the conservation of matter, definite and multiple proportions, and the atomic theory are studied by the results of a series of quantitative experiments. A few preliminary experiments teach the general method of procedure. Then the molecular weight of potassium chlorate is calculated from results obtained by determining the loss of oxygen by heating, and from this molecular weight 48 is subtracted to get the molecular weight of potassium chloride. The molecular weight of silver nitrate is determined by titrating silver nitrate against potassium chloride, since from the actual weights of the reacting substances and the known molecular weight of potassium chloride (previously found) a simple proportion will give the molecular weight of silver nitrate. The results for silver nitrate vary from 167 to 173. The molecular weight of sodium chloride is found by titrating a solution of this salt against the silver nitrate solution and calculating as before. The results of this experiment show that in sodium chloride 40 per cent. is sodium and 60 per cent. is chlorine, and since the molecular weight of sodium chloride has already been found to be 58.5, it follows that the atomic weights of sodium and chlorine must be those parts of 58.5 which are in the ratio of 40 to 60—i. e., sodium equals 23 and chlorine equals 35.5. A previous experiment showed that silver chloride contains 75.28 per cent. of silver and 24.72 per cent of chlorine, but since the atomic weight of chlorine has been found to be 35.5, then the atomic weight of silver by a simple proportion is about 108. If from the molecular weight of silver nitrate (previously found to be 170) we subtract 108 and 48 (the atomic weight of silver and the weight of 3 atoms of oxygen), the atomic weight of nitrogen is obtained as 14. The atomic weight of potassium is found by subtracting 35.5 from the molecular weight of potassium chloride.

After a vote of thanks to the Massachusetts Institute of Technology for the use of the room the meeting adjourned.

Reported by LYMAN C. NEWELL.

Correspondence.

To the Editor:

In the April number (page 107) of School Science apparently two different answers are given to the question, (8) *"To what extent should the English of laboratory notes be corrected by the science teacher?"*

"Emphatically to no extent," the answer of "E. L. M.," is puzzling at first glance. If the writer means that the errors should not actually be corrected by the teacher, for the pupil, then we agree and would add that this seems almost axiomatic. Yet standing right after Mr. Mitchell's answer, that "the science teacher should note and correct errors," it makes him seem to say that he actually corrects the mistakes for the pupils, which he certainly did not mean. As Mr. Mitchell says, in the latter part of his statement, the errors should be constantly *pointed out* to the student.

Apropos of Professor Harvey's two classes in physics referred to in the abstract of his address before the Science Section of the N. E. A., and printed in School Science for September (page 180), it was clear that there was a hole in the fence somewhere, but I did not realize that it was to show more than neglected opportunity for training in the high school. From the correspondence in the October number (page 284) I see that the moral is much stronger—perverted training is worse than no training. Certainly all good science teachers will approve Professor Harvey's sentiments.

L M

Editor of School Science:

At about 8 o'clock of the evening of Oct. 27 occurred a very fine lunar bow, a description of which may be of interest to some of your readers.

The bow showed very distinctly on a light fleecy cloud through which the moon was shining. The colors appeared in the following order, beginning at the inside of the bow: Yellow, orange, red, violet, blue and green, and then these colors were repeated. The yellow, red and green were very bright, the other colors not showing so well. The bow appeared several times, within a few minutes, on successive clouds, as they passed in front of the moon.

Authorities say that these bows are due to the refraction of the light by ice crystals. In this case the cloud appeared to be an ordinary cloud. I have observed two such bows before and in each case there was no cloud as at this time, but simply a hazy appearance over the moon.

Weston, Oregon. Harry C. Doane.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. "Be helpful and be helped."

31. Will someone kindly give the proper strength permanganate solution for making wounds antiseptic? How far will this solution replace corrosive sublimate solution?

32. Is formaline a reliable disinfectant if used in vapor form?

33. In one of the newer elementary textbooks in botany a statement is made that would lead one to believe that yeast can act on starch. On the other hand textbooks commonly give the impression that yeast can act only on sugar. Will someone please give the literature that will answer these questions? Is it the ferment that changes the starch into some kind of sugar in the seed or flour, or does the yeast produce it?

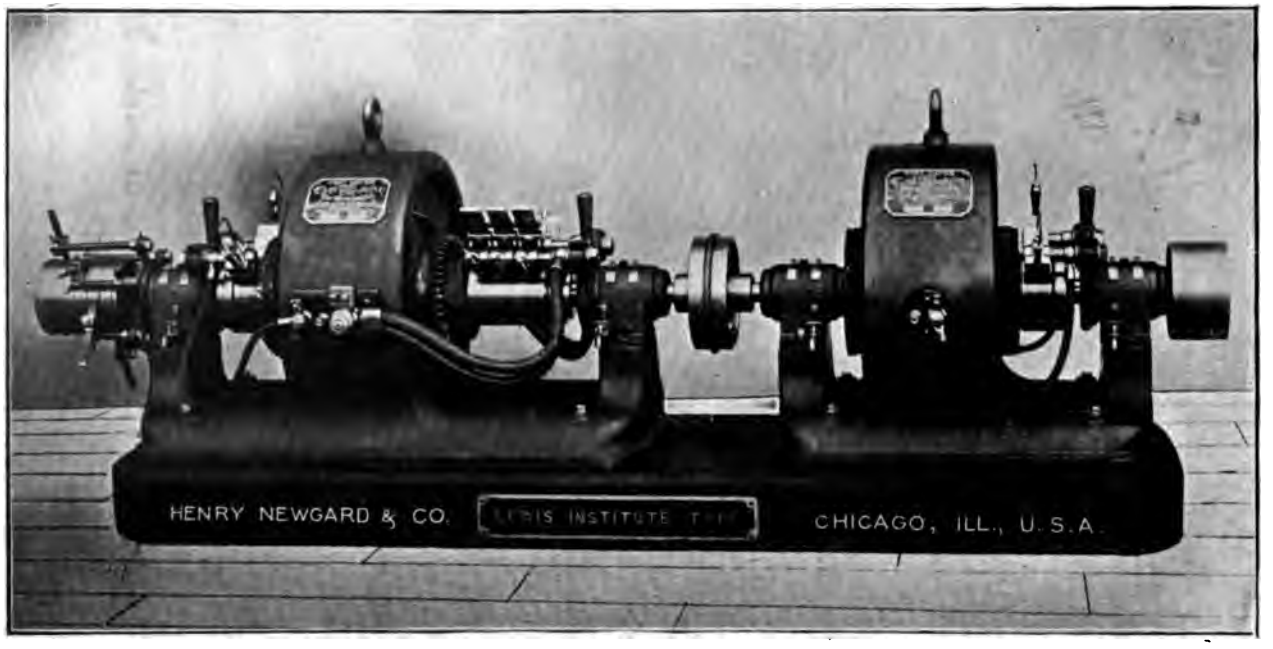
34. Where can one obtain the sticks of Japanese incense for showing the path of rays of light, mentioned in Dr. Porter's experiment, in "Science," Oct. 11, 1901? It would be useful also for demonstrating currents in a room, in the study of hygiene.

35. Has any one else observed anything like the following: One of our students brought in a piece of a weed stem on which were six or seven little paddles of ice, the fluted stem of the weed being the shaft or axis of the little paddle wheel thus formed. The plates of ice were about ⅛ of an inch thick, ⅜ wide and 1½ inches long. An explanation will be welcome.

centuries. Their methods are settled and established. There are, it is true, improvements from year to year, but there are no *radical* changes, no overturning. By comparison with these established, almost consecrated methods, our methods in science are crude and lack elaboration.

"In order to make plain my meaning, let us recall the three chief factors in education. We have, in the first place, to impart information. We have to teach subjects which are valuable principally for the information they yield. Geography is valuable as information. History is valuable, largely at least, for information. These subjects are valuable directly, and in themselves. In teaching subjects valuable for information, we have to guide the student in his selection, assist him in comprehension, and address ourselves to his memory. Another factor we might call mental furniture: the multiplication table is a bit of furniture. It has no interest in itself. Spelling is mental furniture to most of us; much of grammar is simply furniture. With respect to this part of an education the teacher's task is simple; he has but to assist the scholar to learn quickly and remember accurately. The third factor is power: The power to understand, the power to think, the power to reason; what a wonderful power it is. How much it costs! How greatly men differ in that power! In the power to express clearly a definite thought in an orderly sentence, how widely men differ. How much in the way of severe effort do they have to give for that power! How much men differ in the power of consecutive thought.

"Now, Latin and Greek and mathematics are so taught, their methods are so developed that they put before the student a succession of problems which he can, without loss of time, formulate and begin to solve. 'The laboratory methods of mathematics'—I once heard Sir William Thomson speak of a mathematical laboratory, and the phrase pleased me—the laboratory methods of mathematics and Latin and Greek are excellent, thoroughly well adapted to the student. One advantage is that no time is lost in setting before the student the nature of the problem which ought to be solved; another advantage is that nothing tempts the student to forget that it is by some mental effort that he is to



THE CARMAN SCHOOL TRANSFORMER

CATALOG ON APPLICATION.

School Science

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THE HEURISTIC METHOD OF TEACHING*.

BY HENRY E. ARMSTRONG.

"New times demand new measures and new men;
The world advances, and in time outgrows
The laws that in our fathers' days were best;
And, doubtless, after us some purer scheme
Will be shaped out by wiser men than we
Made wiser by the steady growth of truth."
* * * * *
"Our time is one that calls for earnest deeds."
(LOWELL.)

All who seriously study the history of education in our times must agree that, although it may be long ere we can cry *Eureka! Eureka!* of an ideally perfect system, recent experience justifies the assertion that we shall hasten the advent of that desirable time if we seek to minimize the didactic and encourage heuristic teaching; for the progress made of late, which is very considerable, is unquestionably due to the introduction of heuristic methods and exercises.

But many will ask—what are heuristic methods? Even the word is strange to us, they will add.

True it is not yet in the dictionary; but it is scarcely possible to doubt that it is come to stay, and will—nay, must—soon be there; indeed, its introduction as the watchword of a party seems really to meet a want.

* Parts of a Report to the Board of Education of England.

Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer—methods which involve their *finding out,* instead of being merely told about things. It should not be necessary to justify such a policy in education. Unfortunately, however, our conceptions are blunted by early training, or rather by want of training. Few realize that neither is discovery limited to those who explore Dark Continents or Polar Regions, nor to those who seek to unravel the wonders of Nature; that invention is not confined to those who take out patents for new devices; but that, on the contrary, discovery and invention are divine prerogatives, in some degree granted to all, meet for daily usage, and that it is consequently of importance that we be taught the rules of the game of discovery and learn to play it skillfully. The value of mere knowledge is immensely over-rated, and its possession over-praised and over-rewarded; action, although appreciated when its effects are noted, is treated as the outcome of innate faculties, and the extent to which it can be developed by teaching scarcely considered.

Professor Meiklejohn contends that the permanent and universal condition of all *method* in education is that it be heuristic; and goes on to say:

"This view has its historic side; and it will be found that the best way, the truest method, that the individual can follow is the path of research that has been taken and followed by whole races in past times. This has, perhaps, been best put by Edmund Burke, probably the greatest constructive thinker that ever lived in this country. He says: 'I am convinced that the method of teaching which approaches most nearly to the methods of investigation is incomparably the best; since not content with serving up a few barren and lifeless truths, it leads to the stock on which they grew; it tends to set the learner himself on the track of invention, and to direct him into those paths in which the author has made his own discoveries.' It may be said, Professor Meikeljohn continues, that this statement is applicable to science and to science only." But I am prepared to show at the right time that it is applicable to literature also, though not in the fullest extent and application of the method. The heuristic method is the *only* method to be

applied in the pure sciences; it is the best method in the teaching of the applied sciences; and as it is *a* method in the study of those great works of art in language by the greatest minds which go by the general name of literature.

It would be easy to support this contention by numerous other quotations, but one will suffice—than which, however, none could be more impressive or striking. I refer to the words used by Lessing: "If the Almighty were in the one hand to offer me Truth, and in the other the Search after Truth, I would humbly but firmly choose the Search after Truth."

I can clearly trace the development of my heuristic tendencies —which are certainly in a large measure innate, for my father was critical and enquiring—to one of my school books—absolutely the only interesting one that came into my hands—to a literary work, *Trench's Study of Words;* and can well recollect how this book at once fascinated me—and not me alone, but my father also, a commercial man, whose early training and career had been such as to leave him entirely unacquainted with subjects of the kind. I still vividly recall to mind how from this book, as a mere lad, I for the first time gained ideas as to the value of method—of what I should now call *scientific method.* It even taught me to appreciate Euclid, the deadly dullness of which subject long oppressed me, as it does probably almost every boy or girl at school, for there was no meaning apparent in it as it was presented; it seemed in no way to connect itself up with any experience I had gained; but somehow, after reading Trench, the scales suddenly fell from my eyes, its logical character at least became evident, and it was no longer so difficult to understand or to master—but I cannot say that it ever became interesting or its use obvious. This experience has haunted me through life, and has often led me to think how much I might have learned at school had I been properly taught, or even provided with a few books giving insight into method, like Trench's; I owe to it more than to anything else the growth of a desire to promote the teaching of method.

As a student of science I was equally perverse. I had every desire to learn, but didactic teaching seemed always to produce

a sense of irritation. Practical work was intensely interesting, although it was only too often done in obedience to orders without the underlying philosophical motive being clear. The facts recited in the lecture room, especially when accompanied by experimental illustrations, frequently came as revelations, but, on the whole, listening to lectures produced little abiding effect, one image following the other too quickly. Text books I always found unattractive and unsatisfying—often nauseating, for I felt that I wanted to become a chemical cook myself, not merely to know what the dishes were made of and what they looked like on the table; however, I got through them and the measles lightly, without any serious disturbance of mental balance, such as a hard fate, and unreflecting educators, impose on most students who are forced, by the pressure of examinations, to unduly indulge in food so indigestible and unpalatable. Happily the proper corrective was soon discovered; for, being an omnivorous reader, it was my good fortune, at an early stage, to have my attention called to original literature. Needless to say, this proved to be intensely interesting, as glimpses of method were soon gained from it. Full emancipation came later—the haven being reached when I passed from the mainly didactic surroundings of an English laboratory into the heuristic atmosphere of a German university. I seemed to escape into an Elysium.

Nevertheless, in the course of years, I had been insensibly compelled to swallow much poison, and this had its inevitable effect. Impressed habits and convictions were not easily cast aside; so that, when I started my career as a teacher, although I saw much reason to be dissatisfied with existing practices, it was only very gradually that I could divest myself of conventional articles of belief, or make up my mind what changes were necessary and feasible. Therefore I can always fully sympathize with teachers whose convictions have been forced upon them—whose peace of mind was until recently undisturbed. It is easy to understand that it will be very difficult for them to enter fully into the spirit of the heuristic doctrines that are now being widely preached, and still more so for them to apply methods which they have never previously been trained to understand.

PUBLIC LI

It must from the outset and ever be remembered that the great object in view in education is to develop the power of initiative, and in all respects to form the character of the pupil. The appreciation of this contention is crucial. "The pious Pestalozzi is filled with measureless remorse when he finds that he has *given* a little boy a conception, instead of inducing him to find it himself," remarks Professor Meiklejohn. So should every teacher be; and if the feeling expressed in this sentence can but be made to rankle in the mind of every teacher, the end is achieved. Schools will then become educating institutions; the didactic instruction which poisons our existence at the present day will be properly recognized as a fell disease.

It is necessary to insist on this over and over again, as even among those who are becoming advocates of heuristic training there is often incomplete recognition of the fundamental importance of observing such an attitude towards learners. The following passage for example, occurs in the chapter headed "Physical Science" in Spencer's *Aims and Practice of Teaching Physical Science* (London, 1897, C. J. Clay & Sons), to which I have contributed the chapter on chemistry.

"A great deal has been written in favor of the research attitude on the part of the learner. But despite the force of some of the arguments adduced, it may be doubted whether this attitude is the proper one for a beginner. At the commencement of a science course the teaching cannot be too simple, and it must be very clear and definite. Each step taken should logically follow from the work already done, and every experiment should be undertaken with a definite object, which should be fully understood and appreciated by the class. In working out a course of this kind, the *teacher* might, with advantage, follow an imaginary research path into the subject, but the scholars may not become conscious of this, and it is quite unnecessary that they should. If scholars are taught to observe the progress of an experiment in a vague sort of way, and asked to deduce results from their observations, without being told definitely what to look for and how to look for it, the only result of the work is waste of time. In fact, until the scholars have acquired a little knowledge of the subject, it is useless to expect them to reason for themselves in the way necessary to follow out even the simplest research. Reasoning of this kind involves a knowledge of the facts and

principles of the subjects, and a beginner's time is best employed in acquiring this knowledge under the guidance of a competent teacher!"

This presentment of the question may appeal to some who are not versed in the work. It is no question, however, of force of arguments adduced, but one of facts established, and of experience gained in practice among scholars of every type. It is in no sense mere opinion on my part, but a conviction gradually forced upon me and established beyond all doubt by actual trial and observation during many years past, that the beginner not only may but must be put absolutely in the position of an original discoverer; and all who properly study the question practically are coming to the same opinion, I find. Young children are delighted to be so regarded; to be told that they are to act as a band of young detectives. For example, in studying the rusting of iron, they at once fall in with the idea that a crime, as it were, is committed when the valuable, strong iron is changed into useless, brittle rust, and with the greatest interest set about finding out whether it is a case of murder or of suicide, as it were—whether something outside the iron is concerned in the change, or whether it changes of its own accord.

It is of no use for the teacher merely to follow an imaginary research path; the object must ever be to train children to work out problems themselves, and to acquire the utmost facility in doing so. Of course, the problems must be carefully graduated to the powers of the scholars, and they must be insensibly led; but do not let us spoil them by telling them definitely in advance what to look for and how to look for it; such action is simply criminal.

My experience teaches me also that it is the grossest libel on young scholars to say that it is useless to expect them to reason for themselves in the way necessary to follow out the simplest research; but, unfortunately, if you substitute teachers for scholars this is too often a true statement, and here the supreme difficulty of properly carrying out heuristic teaching comes in. It is the teachers who are preventing advance. Let us teachers recognize this; but do not let us overwork and misrate the powers of young children.

Let us try what we can do, and if we do not at first succeed, let us try and try again; we shall surely succeed if we can only adopt this attitude. But, if we fail, let us give up the work as soon as possible, and leave it to others to succeed where we have failed. No other policy is an honest one—for the teaching of young children should never be regarded as a perfunctory task, but as a sacred office. The whole policy of the teacher's duty is summed up in one little word, yet the most expressive in the English language: it is to train pupils to do. On this it is easy to base a simple test of competency.

It is needless to say young scholars cannot be expected to find out everything themselves; but the facts must always be so presented to them that the process by which results are obtained is made sufficiently clear, as well as the methods by which any conclusions based on the facts are deduced. And before didactic teaching is entered upon to any considerable extent, a thorough course of heuristic training must have been gone through in order that a full understanding of the method may have been arrived at, and the power of using it acquired; scientific habits of mind, scientific ways of working, must become ingrained habits from which it is impossible to escape. As a necessary corollary, subjects must be taught in such an order that those which can be treated heuristically shall be mainly attended to in the first instance.

PROFESSOR MORLEY ON THE TEACHING OF CHEMISTRY.

BY LYMAN C. NEWELL.

At a recent meeting of secondary school teachers, Professor Edward W. Morley, of Western Reserve University, made some remarks on "The Teaching of Chemistry." As far as the writer knows, this paper has been published in only one magazine, and

this magazine is not usually read by secondary school teachers. The limited circulation of Professor Morley's views on this subject, as well as his reputation as a teacher of chemistry, a scholar and an investigator, have induced the writer to present portions of this paper to the readers of SCHOOL SCIENCE.*

Speaking of one unfortunate result of immaturity, Professor Morley says:

"I want also to mention a difficulty which affects our teaching, and which comes from the immaturity of many of our teachers. It affects the teaching of science more than it affects the teaching of Latin or Greek or mathematics, for reasons which I shall state later. That immaturity is commonly shown in the fact that the teacher is more interested in the science itself than in the use of the science as an instrument of education, and he therefore at times tends to emphasize those matters or relations which interest himself, rather than to select for his scholars those things which are best fitted for their use at their stage of progress.

"I had in my hands a few years ago a syllabus of a short course of lectures in a university extension course upon chemistry. In the first lecture the lecturer gave three axioms of physics. Why he should have put these into a course of six lectures on chemistry was not plain to me. Then he went on to give what he said were three corresponding axioms in chemistry, and I supposed that there we should certainly have three important and established principles, selected as being especially adapted to a beginner. But one axiom read as folows: 'Every element can be transformed into any other element. Many scientific men do not accept this axiom.' Well, a proposition which not many scientific men believe to be true could be put in front of one's elementary teaching only in consequence of immaturity of judgment. One might as well begin teaching a child his letters with a discussion of the share of Cadmus in inventing the alphabet. This example of the evils which come from immaturity in the teacher may well be an extreme case, but a lesser degree of the

*It should perhaps be mentioned that Professor Morley has revised his remarks for SCHOOL SCIENCE, which will account for their different version in the JOURNAL OF PEDAGOGY, in which the complete paper was published.

same selection of matters which interest the teacher fresh from a year of graduate study, but which are not suited to the needs of the student, are not uncommon. We teach the electrolytic dissociation hypothesis to students who ought to spend the time in learning the relation of acids, bases and salts; or the periodic law to those who ought rather to consider the difference between rapid and slow combustion. The good teacher may well be interested in the periodic law, or in dissociation into ions, with a more immediate and vivid interest, but unless he can also retain a deep interest in combustion and neutralization and the properties of sulphur, for the sake of the pupils under him, he needs to get his bearings anew. It is well that a carpenter should attend evening schools in wood carving, but ill that he should use his carving tools and neglect his planes and chisels next day in making me a door."

His views on the inductive method may be judged by the following:

"The teacher should cultivate soundness of judgment as to what is possible with classes which he instructs. I read the other day some laboratory directions which said that the student should make the experiment, and then make his inference, without being told what to look for. Well, some great men have advanced science by finding the unexpected and the unlooked for—that of which they had no previous hint. But is it possible to find in a class of forty, some thirty-five who can do anything like that? We do well if, having told the student what is the nature of the problem and the method of solving it, we can get him accurately to understand both, and then, after the manipulation is finished, to write an intelligent and adequate statement of the course of thought involved. Not many succeed triumphantly even, when working in this way, they have been led to formulate a definite question which can be answered by yes or no. I give a student a bottle of sulphuric acid and a bottle of solution of litmus, and tell him to find one of the properties of an acid. After a moment's thought he writes: 'A. To determine some of the properties of an acid. B. By acting on litmus with sulphuric acid.' Seeing that

he has thought out the nature of the problem and the method of its solution, I leave him for a few minutes, and return to find that he has written as follows: 'C. Added a few drops of sulphuric acid to a mixture of blue litmus, with a little water. D. The blue color was changed to red. E. Therefore sulphuric acid *is an acid.*' He should have written an inference of the kind which is indicated by his proposition, such as 'Therefore acids turn some vegetable blues to red." A child who cannot find his way across an open field in full daylight to the tree he started to reach is too young to succeed as a diver after hid treasures. Most scientific progress is made by getting in mind a definite question, pondering on some method for addressing this question to nature, making the experiment indicated, making the consequent observation, and deriving the inference which answers the proposed question. Perhaps Faraday could have made observations without knowing what he was looking for as well as any one. But when shown experiments by other scientific men, he was accustomed to insist on knowing first exactly what to look for, so that his whole attention should be rightly directed to the precise matter in question. So, we shall secure the best progress in our scholars if we lead them to formulate a definite question, and a method of getting the question answered, and then to reject as valueless every manipulation and observation and inference which they do not see to bear directly on this question and method. The man who thinks that a student can do much without knowing what to look for, if he really means what he seems to say, has not cultivated a sound judgment as to what is possible."

His grasp of the difficulties experienced in teaching science is shown by the following:

"Another difficulty in teaching science is that our methods of instruction in science are, by comparison with the methods in the long-established studies, pursued by students of the same age, somewhat crude and tentative. This is a real and serious difficulty. Latin and Greek and mathematics, on which the chief onus has fallen, have been well elaborated instruments for teaching during

centuries. Their methods are settled and established. There are, it is true, improvements from year to year, but there are no *radical* changes, no overturning. By comparison with these established, almost consecrated methods, our methods in science are crude and lack elaboration.

"In order to make plain my meaning, let us recall the three chief factors in education. We have, in the first place, to impart information. We have to teach subjects which are valuable principally for the information they yield. Geography is valuable as information. History is valuable, largely at least, for information. These subjects are valuable directly, and in themselves. In teaching subjects valuable for information, we have to guide the student in his selection, assist him in comprehension, and address ourselves to his memory. Another factor we might call mental furniture: the multiplication table is a bit of furniture. It has no interest in itself. Spelling is mental furniture to most of us; much of grammar is simply furniture. With respect to this part of an education the teacher's task is simple; he has but to assist the scholar to learn quickly and remember accurately. The third factor is power: The power to understand, the power to think, the power to reason; what a wonderful power it is. How much it costs! How greatly men differ in that power! In the power to express clearly a definite thought in an orderly sentence, how widely men differ. How much in the way of severe effort do they have to give for that power! How much men differ in the power of consecutive thought.

"Now, Latin and Greek and mathematics are so taught, their methods are so developed that they put before the student a succession of problems which he can, without loss of time, formulate and begin to solve. 'The laboratory methods of mathematics'—I once heard Sir William Thomson speak of a mathematical laboratory, and the phrase pleased me—the laboratory methods of mathematics and Latin and Greek are excellent, thoroughly well adapted to the student. One advantage is that no time is lost in setting before the student the nature of the problem which ought to be solved; another advantage is that nothing tempts the student to forget that it is by some mental effort that he is to

solve the problem. And the contiuual formulating of problems, the continual solving of problems by mental efforts develops power of a highly useful kind.

"But in the laboratory methods of science time is consumed in showing the nature of each new problem, time is consumed in getting the student to understand the method of solving the problem, and much time is consumed in the manipulation required. The time used in understanding the matter in hand is time in which the mind is *receptive,* rather than active; expectant, rather than executive. In the time consumed in manipulation, we all know how busy the fingers may be while the brain rests. After an hour or two of manipulation it is hard to convince the student that there remains any effort of serious thought needed. But, if you analyze the matter, you will see that out of the five processes which go to make up an experiment, four are purely mental processes. The laboratory methods of science are greatly handicapped by the fact that so much time is consumed, both by the teacher and the scholar, in putting him to work with his fingers. There is less time and strength left in which to compel him to think. We all have to fight continually against the danger of letting our laboratory methods in science dilute thought with manipulation. When you set a lesson in Vergil, you merely say, 'Take to the bottom of the thirtieth page. You have thereby set for a student a score or a hundred problems, each of which he can formulate with little loss of time. He knows also the method of solution with no loss of time. He can spend two or three hours in continuous and severe mental effort, hardly interrupted by the consultation of the dictionary. But, when he is given a problem in chemistry, or in physics, the case is different. We refrain from formulating his problem; we indicate its nature in some way, often by letting him read a description of it, and then he is to formulate it himself. It may take him ten minutes or more to think out that he is to write: 'A. To illustrate the law of definite proportions,' even when these words occur repeatedly on the page just read. Then it will take him perhaps longer to formulate the method of getting an answer as follows: 'B. By seeing whether 20, 30, 40 and 50 cubic centimetres of sodium hydroxide

require two, three, four and five times as much sulphuric acid for neutralization as is required by 10 cubic centimetres.' After these are formulated, there comes an hour or more of manipulation. After that the student has to think, 'How does my result apply to the question and method stated at the beginning, and how can I state this relation clearly, accurately and adequately?' This may demand ten or twenty minutes, or more.

"Now it is to be said that there are some advantages on the side of science. When a man has done these things, he has solved a problem much harder and much more profitable to him than any one of the score or the hundred problems which we have imagined as being assigned to him in the lesson in Vergil. But the point is, that after putting to our credit the ten or twenty minutes spent in the operation of reasoning and comparison and judgment in formulating the object and the method of his experiment at the beginning, and also the ten or twenty minutes given to reasoning and comparing and judging about the conclusion, there intervened an hour or more in which the mind was relatively inactive. That was an hour of effort not consciously directed toward a definite aim, but of effort directed chiefly by the physical phenomena around us. With a problem in Latin or Greek or mathematics, or with a series of problems demanding as much time as our single problem in chemistry, almost the whole time is spent in effort consciously directed to a definite aim, and it is such effort which cultivates power. Keeping the eyes and ears open furnishes information, but it does not develop power."

In view of the agitation of the question of the value of chemistry as a college admission subject, Professor Morley's ideas on this topic are timely. He says:

"Many students in our secondary schools study chemistry or physics or botany, not as preparatory to college, but as information courses. Of these I have nothing to say. But of those who study these subjects as preparatory to college, it is proper to speak in this conference of teachers from high schools and from colleges. For these latter students, the development of power is

the important desideratum. This we all know, though many who get the public ear in the public press seem not to agree with us. What are the results of that teaching of science in the school which prepares for college? How do the men who enter the scientific courses compare with the men who enter the classical course or the modern language course. It is not quite easy to answer this question. It is difficult to eliminate the differences in the quality of the men who select the different courses. When a modern language course was first opened to students, it was difficult to compare the results of this course with the results of the classical course, because we could not make the necessary allowance for the differences in the men who entered the two courses. At present, we can make this comparison with some degree of fairness. It is too early to attain the same degree of fairness in comparison of results of scientific and classical courses in the preparatory school. But it does seem to me that men who enter the Latin scientific course in this college have not had, in a year's study of chemistry, a full equivalent for a year's study in the older disciplines. It has been more largely a year of acquiring information, and less a year of self-directed mental effort. Those problems which were solved by the student of Latin or Greek or mathematics were not profound problems, and the mental effort was of an humble order. But it is that activity which is adapted to the age and condition of the student which develops power. In the year of study of chemistry we have not so well elicited that activity which is suited to the powers and the condition of the student. Walking involves but a humble physical process, but it is only by constant walking, day after day, that the soldier can march twenty miles in a day and be valuable as a soldier at the end of the march. It is only by a series of mental efforts, as humble, it may be, as the physical effort involved in walking, that the student gains a power fitting him for the work of the college.

"What are we to do? On that point but little can be said. One thing is that we must use all our ingenuity in putting our science before the student in such a way as will compel the processes of reasoning and comparison and judgment. Our suc-

cess in this depends on the teacher, and on his opportunities, on the equipment which he has at command, the time he has in the class room, the time he has in the laboratory, and the time he has for preparation.

"As far as laboratory study is introduced in the secondary schools, the emphasis ought to be put on something other than manipulation or observation. The ways which one teacher uses may seem whimsical to another. The students may be told, 'the hardest thing you have to learn is that you are here to *study*, not to receive manual training.' Perhaps they are told of what steps an experiment properly consists, and are requested to make their notes in accordance with this analysis. They may be directed to put under (A) the object of the experiment, under (B) the method of solving the problem stated in (A), under (C) the manipulation, under (D) the observations made, as far as they bear on (A) and on (B), carefully excluding anything irrelevant; under (E) the inference, being careful to exclude all inferences which do not bear on (A) and (B). Perhaps the teacher will wisely insist that no experiment be ever begun before object and method are considered and recorded in the note book, and may dismantle the apparatus set up or throw away the results attained, in case of a student who hastens to put sodium in water before he can take time to think whether he ought to propose to make hydrogen, or to show that water contains hydrogen. He may perhaps say that the student will be likely to suffer an uncomfortable five minutes, who confuses one of these five matters with another, and puts observation with manipulation, or inference with observation; and may be ingenious in ways of creating five minutes of discomfort for the thoughtless. He may insist that four-fifths of every experiment, as seen by this analysis, consists in a mental process, and laughingly encourage the student to spend at least a minute an hour in thinking. So, in a hundred ways, the teacher can assist students in remembering that it is mental development that they seek, and that it is the processes of reasoning, of comparison, of judgment, of invention, of discovery, which are to be exercised.

"In the recitation room something can also be done to make a

recitation somewhat more than a test of the memory. It ought to present to each student a problem in the art of putting a matter clearly and in well-ordered sentences. He may be led to see that to *understand* a matter is but a trifling attainment, as compared with a certain kind of *mastery* of the lesson, which enables him, when standing up to recite, to solve the problem of so putting that lesson before an intelligent audience as to be easily understood."

CAN WE INTEREST THE PARENTS?

BY E. L. MORRIS.

Under the conditions of teaching in the district schools of the eastern part of the United States, in the early days, the teacher, or school master, as he was called, was thrown much with the parents of his pupils. His contact with them was perforce to some extent, for he "boarded round" in the more well-to-do homes. He had opportunities of studying the home influences surrounding the boys and girls. He often could profit by silently listening to some home discipline, and from that time both in kindness to the parent and in justice to the boy, draw out the best in the overgrown youth. Boys and girls were misjudged by their parents, as now, because their parents failed to remember their own point of view at that age. Many were the teachers, however, of the prime of life, who knew well the awakening mind and life of the awkward student. In those days it rested on the individual character of the teacher whether he enlisted and turned to the profit of son or daughter the interest of the father as the family sat around the table after the supper things were put away, or won the sympathy of the mother.

In these days the situation is quite different, and more markedly so in the cities. In the country, the teacher can still retain some of the old-time influence through the parent's coöperation, especially if the students are few. In the towns and middle-sized school centers, there are more interruptions and fewer opportuni-

THE DISPLAY OF BIOLOGICAL WORK.
The Botanical Laboratory, looking southeast. (Taken by A. A. Doolittle, Instructor.)

ties and desires for social acquaintance between teachers and their constituents. In the larger cities, outside the corps of kindergarten and lowest grades teachers, there is among a few the feeling that naught but purely professional relations are desirable, while the opportunity for any other is very small. We certainly have today very little of the former knowledge by the parent of the teacher's work and the pupil's difficulties and successes. The value to the pupil and the teacher of all the coöperation which teachers and parents can give to each other has never been questioned. The fact that it has lessened, due to general trend of circumstances, is none the less patent.

The question which confronts us is how may the old-time benefits of coöperation be enjoyed under the present circumstances of so widely diversified interests. Under these circumstances, too, there must be grouped with the parents the public men and the childless taxpayers, the public press and opinion, of each community, then of each commonwealth of communities. To gain the coöperation and encouragement of these people is a much greater

labor than the school master had. Greater, because more of special effort is necessary to get their attention, to hold their interest, and to inspire their activity.

In an eastern city, under the need of bridging a gap which had formed by the development and change of the courses of study, the high-school authorities inaugurated the following plan. Various efforts had been made to acquaint and interest the public in the high-school work. For various reasons, unimportant here, the efforts were without appreciable results. But the people must be interested. So, in the spring, a demonstration was determined upon. It must be noticeable to attract the attention of the people. Invitations, printed, written, oral, official and personal, were issued by officials, teachers and pupils, to an "Open House" of the high schools. These "Open House" demonstrations were conducted one or two days in each of the buildings, so that citizens from every part of the city could find it convenient to attend. The hours were planned to further accommodate working people, as well as more leisurely folks. The invitations contained a statement of the features the public might expect to see. These features were representative work already done in the high schools and actual schedule work being done by the pupils in the regular classes. The instructors were engaged in directing the working pupils or showing and explaining the work to the people. The manual training exhibit was taken from building to building, instead of remaining at its own building alone. The other buildings showed practically their own work, there being a few exceptions in some departments. The language department had extensive sets of papers, both recitation and home preparations, as originally presented in every case, "corrected" or "uncorrected," and tables strewn with the text and reference books characteristic of each. The work in mathematics was largely the same, together with various blackboard demonstrations. Drawing and painting practically followed the plan in the sciences, given below.

In the natural sciences, perhaps, there was the most show, but none the less of training and education. The laboratories were in full working order. Regular work, by classes in course, done during the year or in progress, was carried on by the pupils. Each step in each kind of work was illustrated. The object, plan and

THE DISPLAY OF BIOLOGICAL WORK.
Zoölogical Laboratory, looking southwest. (Taken by A. A. Doolittle, Instructor).

results both expected and realized were posted. Everything was carefully labeled, giving all the information one might care to read. Instructors and student assistants were busy answering questions by the visitors. The buildings were crowded, every age and station being represented. The enthusiasm was great.

But the after effect was and is the better measure of the result. Greater personal interest by the parent in his child's work and success is very evident on every hand. The active pupils are showing a better spirit of work, probably because they then got their first bird's-eye view of high-school work. At the same time they thoroughly read every exhibited paper which they could understand. The public press has moderated in its criticisms on pending school questions, and has published fuller reports of school matters and interests, than had been the case. Larger appropriations are under way. On the whole, every line has been benefited by the aroused interest. Parents now come into the schools for better understandings and decisions, and for personal pleasure.

What can be done in places where circumstances differ from those met with in this experience?

BOTANICAL FIELD WORK IN SECONDARY SCHOOLS.

BY H. S. PEPOON, M. D.
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I take it to be a proposition readily accepted by the up-to-date instructor in botany that plants are not simply to be studied as mere structural objects composed of cells and variously named parts, the end of such a line of work being a morphology of greater or less excellence; neither are they to be viewed as mechanisms with various parts performing each its own peculiar labor, the goal being a physiology of every known organ; but, rather, that linked to these in as firm a union as conditions will permit, there is to be added a knowledge of plants as living beings, affecting and affected by surroundings, animate or inanimate, and these factors in their ultimate outcome leading to changes in the plants themselves, or in the environment in which they are placed.

Speaking more particularly from the standpoint of the conditions as found in the Chicago high schools, I am certain that there never has been a time in their history more favorable for field study than the present. The botanical and zoölogical sciences have been accorded time more proportionate to their general and specific value as educational elements, and the whole school year is now given to each. This allows time to study phases and details of work which had to be omitted when the periods were shorter.

A whole year devoted to botany is a great advance, but there are many difficulties in the way of field work that can be appreciated only by one conversant with high-school methods and conditions. I propose to take up these difficulties somewhat in detail in the order of their real or seeming importance. To many these difficulties are not new, and my only excuse for presenting them is that I may offer some sort of solution or plan by which, in a large measure, the difficulties may be overcome.

In considering any such subject, there are, I believe, three dif-

ferent and perhaps somewhat antagonistic points of view to be remembered; that of the scholar, of the teacher and of the school in general, and it is only as we can correlate these that we arrive at less or greater success.

The great obstacle in the way of systematic field work in botany is the inflexible daily programme of the high school. A pupil takes four studies that come so many times a week on certain days and at certain hours. It is next to impossible for him to absent himself from Cæsar, geometry or English without seriously affecting his standing in those subjects. And yet it is often impracticable to have field study under the teacher's direction without some such infringement on the time of other studies. I am referring here, of course, to time taken from school hours. The matter is not presented in a much more favorable aspect if the systematic field work is attempted after school, for then the complaint is made that botany takes the time that ought to be devoted to study for coming recitations.

As a remedy for this condition the writer has tried double laboratory periods in the afternoon. With a programme arranged in this manner, classes may leave at noon for trips to the surrounding country, not occupying more than half a day, and no violence be done to other studies on the daily list. Such an arrangement is strongly advised, not that frequent use may be made of it, but that use *can be made,* when necessary. This, however, is of only limited application, and often not feasible at all with certain classes, and so may be considered a possible but only partial solution.

A second difficulty is the large size of the average high-school botany class. If the teacher be allowed to do field work at all, under his personal supervision, he cannot do it frequently with small classes, for this plan would beget the difficulty mentioned before. On the contrary, he must make infrequent trips with classes say of one hundred. Any teacher who undertakes to guide one hundred enthusiastic young botanists in field work, and sees that each one improves the opportunities presented as fully as possible will have a large and difficult problem to solve.

This difficulty may be partially met by making afternoon

trips with sections of the class. There is no remedy, however, if the entire class goes on the trip, and if the subject be properly presented, there will be no relief from limited numbers taking the subject as part of their school work, for both boys and girls will be earnest and eager workers in the botanical field, and there ought to be no method invented to discourage them.

Again, I have found by practical experience, that the expense to the individual pupil (if field study on a large scale is attempted), is often a serious matter. If the teacher wishes his pupils to learn the peculiar characteristics of, and the effect of environment on, the dune, bluff, ravine, valley, prairie, wood or marsh vegetation, trips to such localities are necessary, and will often be found beyond the means of many pupils. This is a subject demanding the serious attention of all educators, and the hope is expressed that the day is not far distant when steam and surface railways generally will make such rates for parties of pupils under the charge of instructors that the expense will be largely diminished and that this sort of country outing will be established on a permanent basis.

These are the chief obstacles to be encountered, but there are other minor ones that will cause more or less trouble. The regulations governing such field trips by our Chicago schools is a difficulty of possibly prohibitive effect, but it is to be hoped that time and a fuller appreciation of the value of such work may largely or entirely do away with such restrictions.

The disinclination on the part of the instructor is, I am aware, a delicate matter, for it would seem that the properly trained and enthusiastic botany teacher ought to delight in such labors, and, indeed, be it said to his credit, he generally does. We are prone to forget, however, that there are very many items of drudgery and clerical work inseparably connected with the teaching of science, botany being no exception, that use up vital energy and cause the tired teacher to long for rest, rather than for some fatiguing field trip.

Lastly, it will be found that a minority of the class do not take kindly to field work, as representing too much physical labor, perchance.

These several difficulties are largely gathered about the person of the instructor in a way that renders it very hard for him personally, to conduct this field work. Doubtless the best results are to be obtained only in this manner, but I am sure this is not the only manner in which good results are to be reached. I do not intend to minimize in any degree the influence the teacher ought to wield in all field work, but that such work is impossible without his presence is a grave fallacy. Original and helpful field work may be accomplished while the instructor remains within his laboratory, exerting, however, a controlling and directing influences over all the studies undertaken.

There are two distinct lines of field work that may be taken up by the botany class. The first has to do with the more or less exhaustive study of single types of plants, with all their surroundings of physical environment and competition and regulation by other organisms, plant or animal. It is desirable to obtain as thorough a comprehension of their life phenomena as possible, and all the elements that enter into their existence as *living beings,* capable of acting and reacting.

The second line of inquiry has to do with plants, in the aggregate; what are the reasons that influence the formation of similar structures in diverse plants when occupying like positions of growth; the determination of the rules and regulations that govern the great plant societies which give to the natural landscape such marked and characteristic features; the study of vacant lots and of circumscribed areas, working out in a small way the great problems of plant distribution.

In both these undertakings the fundamental idea is that the plant is not a mere inert *specimen,* merely to be pulled to pieces or cut up, but that it is a living organism, fully capable of working out for itself its own salvation, if surrounded by favorable environment, and capable also of materially affecting the careers of other organisms with which it comes into contact.

To carry out these two lines of work in a definite manner, so that definite results may be obtained, I know of no better plan than to furnish each student with outlines which will direct his studies in the field without the presence of the instructor. The

questions should be definite and should compel the pupil to *observe* and *to think*. Questions answered by "yes" or "no" ought to be few in number, but those in which reasons and conclusions are called for, in addition to correct observation, should abound. It does not detract in the least from the value of the resulting answers that some of them may be erroneous, or that wrong judgments are formed, or illogical or faulty conclusions drawn.

The following are outlines which have been used and found to be successful and are appended as suggestive aids:

A FIELD STUDY OF LICHENS.

1. General directions as to localities to be visited may properly head the outline.

2. Special *questions* and *observations*. Take notes and make sketches of important features.

(*a*) Upon what do you find lichens growing?
(*b*) How do they differ in different situations?
(*c*) If growing on trees, what parts of the trees are occupied? Why do they grow on such parts?
(*d*) Do they prefer live or dead trees?
(*e*) Do you think lichens injure trees? Give reasons.
(*f*) What colors do you observe?
(*g*) Is chlorophyll found in all specimens?
(*h*) Does the color remain constantly the same? Observe carefully and explain.
(*i*) What is the food of lichens?
(*j*) What protection have lichens from cold?
(*k*) Lichens may be found on buildings and fences. If so, what is the character of these structures?
(*l*) Examine carefully for animals.
(*m*) Lichens generally contain Pleurococcus. Why are they not as common as that plant?
(*n*) Why are lichens not common on street trees?
(*o*) What kinds of trees (if any special ones) do they prefer?
(*p*) What conditions favor the presence and growth of lichens?
(*q*) Examine carefully for fruiting "cups." Are they common or not?
(*r*) Why do so many lichens form "rosettes?"
(*s*) If possible, compare rock and tree lichens.
(*t*) Of what advantage to many lichens is their close contact with the objects they grow on?
(*u*) What effect has water on lichens? Why?
(*v*) Note any other interesting facts you may observe.

A STUDY OF A WEED COMMUNITY.

1. Carefully observe the different varieties found in a given area.
2. Take a census of each kind and make a table to show comparative numbers.
3. Examine each variety for peculiarities as to size and number of leaves; hairiness, general dryness, or succulence.
4. Examine the roots to determine character and the life duration.
5. If in season—examine fruits or seeds.
6. Answer, if possible, the following questions:
(*a*) If one kind is more abundant, find reasons, if possible.
(*b*) Why are most weeds annuals?
(*c*) How do perennial weeds differ from annuals?
(*d*) Why are weeds usually hairy?
(*e*) Why are most weeds of a dry nature?
(*f*) What character of flowers do weeds have?
(*g*) What becomes of all the seeds produced on a given area.
(*h*) Why do weeds produce so many seeds? Estimate the seeds in different varieties.
(*i*) What are the characters of weed seeds?
(*j*) What determines which weeds survive?
(*k*) Why is it so difficult to eradicate weeds?
(*l*) What effect has drouth on weeds? How do they compare in this respect with garden plants?
(*m*) Do animals usually eat weeds? What reasons can you find to explain the conditions in this respect.
(*n*) Do weeds serve any useful purpose? Explain.
(*q*) What are the qualifications of a successful weed?
(*p*) Why are weed areas not covered with the same weeds each year?
(*q*) How are weeds distributed?
(*r*) Why do not all weed areas have the same weeds?

A STUDY OF PLANT SOCIETIES.

1. Carefully observe all the plants of as many diverse areas as you are able to find, especially those that are very dry and very moist.
2. Examine for each plant the character of root, stem and leaf.
3. Tabulate results after seeking answers to the following questions:
(*a*) Compare the plants of each area as to stem growth (herbs, bushes, shrubs, trees).
(*b*) Examine for variety of forms in each area. Why are there often so many plants of one kind in a given area?
(*c*) Why do plants of dry places often develop tap-roots?
(*d*) Explain why plants with numerous fibrous roots, tap-roots or fleshy rhizomes may grow in the same dry surroundings.
(*e*) Where do you find plants with the greatest amount of hairy covering?
(*f*) Can you give any reason for result found in *e*?
(*g*) What protective devices do you find stems possessing?
(*h*) What relation do you find between soil and root form and extent?

(*i*) What relation do you find between moisture and root direction?
(*j*) What peculiarities of covering, if any, do roots have?
(*k*) Why do many plants have rhizomes or underground stems?
(*l*) Where do you find herbs with largest and smallest average leaves?
(*m*) Why do you find so few water plants that are not smooth?
(*n*) Examine carefully plants of dense shade for hairiness, leaf-size and other peculiarities.
(*o*) Do the same for plants always exposed to the sunshine.
(*p*) Examine given areas for plants related to each other.
(*q*) Study plants for a season. Do you discover spring, summer and autumn societies? What common features do you find for each?
(*r*) Can you find members of one society migrating into the area of another society? Do the migrated plants thrive?
(*s*) Sketch plant-society areas, giving soil, moisture and sunshine data, with census of *common* plants.
4. Seek for general rules governing plant societies, as shown by results of your observations.

The pupils with these outlines work on the subject when they choose, and as a rule are not accompanied by the teacher. When their reports are handed in, there is a general discussion by the class, that each may obtain the benefits to be derived from the observations of all.

At the same time the pupil derives four distinct and very important benefits from this kind of work: First, he learns how to do independent work without the presence of others; secondly, he learns correct methods of observation and how to record his observations; third, he becomes acquainted with plants as living beings; and, finally, he receives needed and healthful physical exercise accompanied by delightful mental stimulus.

THE OLD AND THE NEW IN PHYSICAL GEOGRAPHY.

BY L. H. WOOD.

Now and then we catch glimpses of the good work done in geography in some of our normal schools and universities; again and again we hear reports of the progress made in the German schools in every branch of geography; several good journals are constantly pushing to the front plans of work and exhortations to enterprise in this direction; excellent text books are being published, and some of the older and poorer ones have been laid on the shelf forever; teachers, generally, are alive to the conditions, and are satisfied that some great changes must soon take place in methods as well as material; these facts suggest "something new."

The use of the term "new" does not imply that no good work has been done in the past, nor that the old methods and the old teaching were all bad. Rather the "new" is an evolution, a survival of the best that thorough going teachers have used, coördinated with the recent ideas that are receiving the stamp of approval after a fair trial.

Like the phases of progress in other lines, the "new" in geography must come in gradually. Conservatism must temper enthusiasm. There is earnest devotion on the part of so many teachers to this subject, that the "new" may safely be grafted on the "old" and the two grow together until the graft becomes the fruit-bearing limb. Leading educators have already stated what the "new" should be, and in doing so have indirectly outlined the "old." So that, had *doing* followed sharply on the heels of *saying,* the new era would have been upon us long ago. But the inertia of the large mass of prejudice and ignorance must be overcome, and the "new," for some time, will be concerned with this task. The great universities and normal schools certainly have taken hold of this problem by the right handle. It now remains for superintendents and principals to do their part in coördinating the work of high schools and grades. This done, the millenium of geography will have dawned upon us.

As the high schools look to the universities for teachers to do a special work, so the grades must look to the high schools for teachers to do their special work of introducing correct methods in geography. As the high school supplies young teachers with correct notions of language, history and mathematics, so it should supply them instruction in the best methods of geography and normal ideas of what the material used should be. This creates a demand not only for teachers of the high-school branch of geography who know what the instruction in the grades should be, but also a certain part of the course planned with reference to the needs of the grades.

Such an arrangement of the high-school work need not impair the integrity of the secondary course in the science of physical geography, but will, as I shall try to show, be mutually beneficial to both classes of pupils.

The loose relation that exists between grades and between the grades and high school strikes me as the phase of the "old" most to be criticised at the present time. Where the superintendent is a disciple of geography, there is usually much stir along this line, and many plans and outlines are issued monthly, designed to systematize the teaching of the great mass of facts loosely combined under this subject. When the superintendent can teach the physical geography of the high school, he will, necessarily, flavor the programmes of work for the grades with the aroma of his own interest, and thus the high school and grades will be connected in part. But this is not the case in most schools. In fact, what I have learned from the majority of schools that I have visited, and from inquiries made in many parts of Michigan, not even this loose relation exists. As Mr. W. H. Snyder, in an article written for this Journal (March and April, pp. 20 and 62), so pointedly says: "The geography of the high school occupies a place where there can't anything else be easily put; it is taught by the teacher who can't do anything else very well; taken by the pupil not exactly suited for anything; taught with any book that is easy." Such a condition exists largely because the study in the high school is really the culmination of nothing that precedes; is not closely related to the geography that has occupied

the mind of the pupil for several years of his grade work, and has not, so far, been sufficiently useful to grade teachers to make it worthy of its place. But give the study its rightful place as the coördinator of the many facts gathered from the study of many lands in the grades, the loom, as it were, in which the loosely connected facts of political, physical, commercial and biological geography are neatly woven together into the fabric "Geography"; make it helpful to the young teachers who go from the high school to the grades; introduce into the course some of its bearing upon history and civilization, and it will soon come to occupy no mean position among the culture studies so long holding the favored places on our high-school programmes.

How can this be done? How can the high-school course be brought into closer relation with the grade work? "Aye, here's the rub." What part of a system will make the teacher of physical geography, if not an integral part of the geography department, at least in sympathy with those teachers who bear the burden of the subject? Several things are necessary to take teachers and subject out of the "old" rut and balance things up on the "new" plane.

In the first place, some teacher well versed in the subject must be given charge of the department from cellar to garret. What would become of the department of music and drawing in our schools if there were no head? And what can be expected from geography where as many loosely-related topics are left to be patched into a connected whole by a dozen different people? The "new" in thought and method must be grasped by some devoted teacher, and its truths be preached from the housetops until the corps of grade workers is converted. *Then* coördination will have begun; one grade of work will not overlap another; high-school work will supplement grade work; physical geography will be introduced in proper proportion in the first grade as well as in the last, and the several phases of geography will come to receive, each its own share of attention in all the grades, because they have snugly nestled down to partnership in the mind of the teacher. In the past there has been too much dissection of the subject into its vital parts—into physical, political, commercial. A book has

been written in which the physical occupies the first half, and teachers have taught this text page by page, with the feeling that because the author was a great geographer, therefore the order of treatment should be religiously followed. This same book presents the physical geography systematically, in a more attractive form than do many of the high-school texts, with the result that when the pupil reaches the presumably more complete text he finds it dry and his interest takes a drop. Because this book emphasizes the physical too much, superintendents in many cases have gone back to the books that give the pupil more so-called information on the many important phases—as capes, bays, crooks and turns in the coast line, *et cetera,* from map questions. And as teachers turn once more to the cut and dried question-and-answer method of the text; so bad, because it binds the child down to too much serving of the text book, when his mind should be wrestling with the problems of his own environment and roaming to and fro upon the earth gathering data for the construction of his own geography. To overcome prejudice in this matter and institute a plan of work in which all the parts have their true balance, the specialist is needed. He must enter into the work in geography in the grades, as the drawing teacher enters his department. He must teach and inspire the teachers whose views of the subject are generally narrow and who like, as we all do naturally, to do their own little piece of work, forgetful that their piece joins others to make up the whole.

Such a special teacher might teach the physical geography of the high school; for, knowing the condition of the grade work, he could properly coördinate the primary and secondary phases of the subject. He might call his high-school course simply geography, and in it offer the material in such a way as to supplement the necessarily fragmentary teaching of the grades. He could thus adapt his course to the needs of the school, and at the same time train teachers to enter intelligently upon the grade work. He would certainly be able to illustrate the principles of physiography by type studies, too, at various points of the earth, and make due reference to the multitude of facts that illustrate every principle that he brings before the class. Then he would prove truly that

physical geography is based on the earth and not on the text book. His course would not then be a conglomeration of a half dozen sciences, but would stand forth among them all in its true place as a science, holding its own with proper dignity.

It is to be supposed that the child leaving the eighth grade has been taught to apply the more obvious truths of physiography to history, and that many of the simple facts of nature are already his own private property, acquired by the use of his senses, in and about his own home land. In geography proper his work has dealt with facts rather than with relations; he has been working in the inventory stage of his science; he possesses a large stock of facts concerning form, size, position and location of the natural features of the globe. Home geography has been pretty fairly mapped out. He has also begun work in the second stage of his science by tracing the relationship of many distinct groups of phenomena. He has studied the relation between deserts and mountains, deserts and rainfall, rainfall and rivers, rainfall and fertility of soil, gulf-stream and climate, movements of the earth and climate, the effect of temperature on plants, water and animals, the effect of temperature on the air, and many other such sets of relations. He has, in short, looked out of the geographical window of his soul to view the panorama presented by the organic and inorganic phenomena of the round world. If the pupil has such an equipment as this he should be fitted for good, solid work in the real science, physical geography. Having seen considerable of the human element in geography and history he can consent now, for a time, to be led away to the purely physical phenomena about him.

As high-school teachers we must limit ourselves on the side of fact and open the window of the soul on the side of relations; for this is the distinction between the primary and secondary aspect of the science. We must cause the pupil to experience as much pleasure in his tide of emotions arising from his conquest of a world of relations as he formerly did from that of curiosity in the accumulation of the facts. We must teach him that the power of seizing relations is the passport to this new land of promise. Too often the child does not have this passport on coming

to the high school, but has, rather, a thorough dislike of the subject acquired through bad teaching. When this is true the high-school teacher must take the pupil as he is and not as he is supposed to be. He must re-dress the old facts and bring them out clothed and in their right relations. When we have reached the strictly "new" era the necessity for this elementary work in the high school will be done away, and the broad reaches of a world-wide, beautifully true science will be laid open to the student of our high schools and academies.

THE PURIFICATION OF MERCURY.

BY GEO. M. HULETT.

Instructor in Chemistry, University of Michigan.

Many methods have been proposed for the purification of mercury in the "wet way," that is, by using acids and oxidizing mixtures, such as nitric acid, a mixture of nitric and sulphuric acids, and especially a mixture of sulphuric acid and potassium dichromate.

The impure mercury is shaken up with these reagents, or it is allowed to fall in a fine stream through a long column of the reagent. But with these reagents, none of the metals which are below hydrogen in the voltaic series can be removed unless some mercury is in solution. When mercury is dissolved in the reagent, however, all metals down to mercury in the series can be removed, except gold, silver, potassium, etc. As these "noble" metals are seldom found in mercury, the wet way is useful. The best reagent is a solution of some mercury salt, and a nitric acid solution of mercury nitrate of medium strength answers all purposes. A large jar partially filled with this solution serves as a receptacle for all "dirty" mercury. The mercury to be purified is brought into a separatory funnel (Squibb's form with a glass stopcock and stopper is best), and covered with a freshly prepared solution of mercury nitrate and nitric acid. After the mer-

cury has been shaken vigorously with this solution for about five minutes, it is run into another separatory funnel, and the solution is poured into the dirty mercury jar. The mercury is now shaken with a little water two or three times to remove the acid, and finally dried by allowing it to pass through a pin hole in the apex of a folded filter paper. This leaves the mercury very bright and ready for all ordinary uses.

It is, however, often desirable to distil mercury, and this can be done easily with ordinary laboratory apparatus, using no better vacuum than can be obtained with an ordinary Sprengel aspirator or filter pump. A and R (Fig. 1,) represent two ordi-

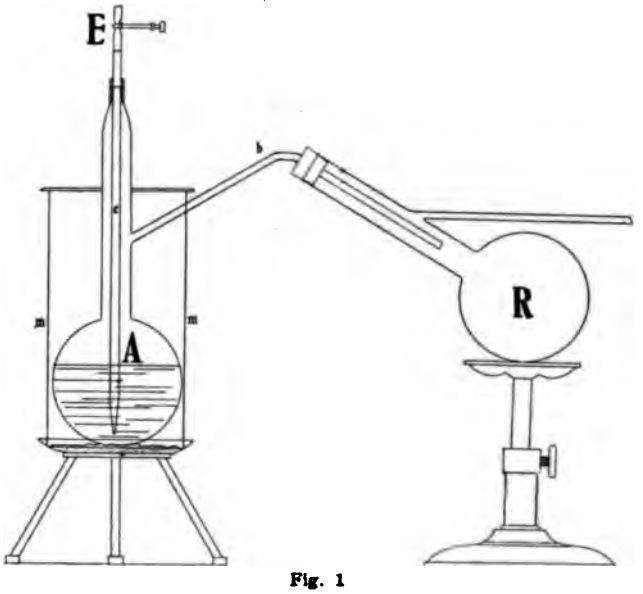


Fig. 1

nary distilling flasks of about half a liter capacity. The side tube of the flask A is bent first up and then down, and, if necessary, a short piece of tubing is fused on to this side tube to make it 30 to 40 cms. long, so that it extends well into the neck of the receiving flask R. The connection with R is made air-tight by means of a rubber stopper, or, better still, with a cork and sealing wax. The side tube from the neck of the receiving flask R is

joined to an ordinary Sprengel aspirator which gives a vacuum of from 20 to 30 mm. of mercury.

If one attempt to distil mercury under atmospheric pressure or in anything less than the best vacuum obtainable by a mercury pump, the mercury bumps and spurts beyond all control. But if gas bubbles are allowed to pass slowly through the mercury, it boils gently under any pressure, and in an ordinary Sprengel aspirator vacuum at about 210°C. This use of gas bubbles to prevent bumping in liquids being distilled under reduced pressure is quite common in Organic Chemistry manipulations.

To introduce the air bubbles, a piece of common tubing of rather thick wall and 6 to 8 mm. in diameter is drawn out to a fine capillary at one end—about one mm. in external diameter and 10 to 20 mm. in length. This capillary end extends down into the mercury in A, and the upper end of this tube *e* bears a piece of rubber tubing with a pinch cock to regulate the admission of air. The joint between A and this tube can be made air tight with a minimum exposure of rubber or cork, if the neck of A be drawn down so that it just slips over the tube *e*, the joint being closed with a piece of rubber tubing. If the neck of A is rather long and the mantle with asbestos cover described below is used, this joint never becomes noticeably warm.

The flask A stands in a sand bath on a tripod and is surrounded by a mantle *m m*, made from a large beaker, the bottom of which is cut off with a "cracking coal," and a slit cut down from the top for the side tube *b*. The top of this mantle is closed by means of an asbestos board cover.

The mercury is placed in A and the end of the capillary part of the tube *e* pushed down nearly to the bottom of the flask. The aspirator will soon reduce the pressure to about 25 mm. of mercury, if the joints are tight. Then by slowly opening the pinch cock, a slow stream of bubbles is allowed to break up through the mercury. A Bunsen burner serves as a source of heat, as a temperature of only a little over 200°C. is needed under the diminished pressure. The distillation can proceed quite rapidly without any danger of spurting, and when once in operation, the apparatus requires no attention whatever. One can safely allow

all the mercury to distil over, as the flask will not break and the last portion is quite as good as any. My results showed the absence of foreign metals in any part of the distillate (and it was possible by the method used to detect, for example, one part of zinc in 100,000,000 parts of mercury).

If any metallic oxides are present, they are liable to be mechanically carried over, and form a coat or covering on the mercury, but no *metal* except the mercury goes over. The oxides, if present, are easily removed by filtering through a pin-hole in the apex of a folded filter paper.

This apparatus is readily constructed from material found in most laboratories. It has a far greater capacity than the Weinhold mercury still; it distils more rapidly and possesses the decided advantage of distilling all the mercury, whether a few grams or kilograms.

In distilling from an iron still at atmospheric pressure, the bumping and spurting leaves one in doubt as to the purity of the distillate. This difficulty could be easily obviated by forcing a slow stream of air from any compressor, or hydrogen from a generator through the boiling mercury.

Pumice stone, pieces of porous plaster, hollow tetrahedrons made of platinum foil, etc., are often used to prevent bumping. They owe their efficacy to the little air bubbles which are liberated from them and tend to restore the equilibrium between a liquid and its vapor. The liquid in the interior where it is not in contact with the vapor becomes superheated; a bubble of an indifferent gas, brought into the liquid, acts as a vacuum to the vapor, and as soon as the vapor forms in contact with the superheated liquid, the system is out of equilibrium, and there is a rapid evolution of vapor while equilibrium is restored. The return to the equilibrium temperature is often so rapid as to cause explosive effects. The gas bubbles prevent superheating, and the liquid boils quietly at the equilibrium or boiling temperature.

Porous substances, after a time, lose the gas on their surfaces or in their interstices, and so become ineffective. A slow stream of bubbles of an indifferent gas is generally more effective. If working under diminished pressure, one uses the pressure of the

atmosphere to force the gas through the boiling liquid, and at atmospheric pressure, one can employ a gas from a gasometer, gas cylinder or generator, according to the nature of the gas to be used.

A DEMONSTRATION OF THE WEIGHT OF A LITER OF CARBON DIOXIDE.

By C. E. Linebarger.

There are comparatively few quantitative experiments which are adapted for performance on the lecture table, as they require more care and attention to insure good results than can usually be given during the lecture. And yet the desirability of giving some quantitative work in the lecture room can hardly be questioned. A fundamental demonstration is the determination of the weight of a liter of a gas, and in schools where the laboratory work is purely qualitative, such a demonstration becomes almost peremptory. Carbon dioxide is a gas well suited for such purposes. The methods which have been in vogue are, however, rather unsuitable for demonstration, although they may be made to yield satisfactory results in the laboratory as an individual experiment. The method described in this paper permits of the weighing of a liter of carbon dioxide with a satisfactory degree of accuracy, and in a reasonably short time, and further does not demand any protracted or delicate manipulation. If the class is familiar with the reduction of gas volumes to standard conditions, the demonstration from start to finish ought not to take more than half an hour, and the actual manipulation of the apparatus, apart from the weighings and measurement of the volume of the gas, does not require five minutes.

Recently there have been placed upon the market steel capsules* filled under considerable pressure with carbon dioxide.

* Their trade name is "Sparklets."

They are manufactured for the purpose of making sparkling or soda water in small quantities, a bottle of special design being provided with a simple device to open the capsule and discharge the carbonic acid gas into the water with which the bottle is filled. The "pint size" of these capsules contains about two grams of carbon dioxide, and the capsules weigh about six grams each. With these capsules, the exact weight of about a liter of carbon dioxide may be found; the capsule is weighed, then opened so that the compressed gas may escape, and the capsule, now filled with air, reweighed.

The apparatus employed is shown in Fig. 1. With the exception of the "capsule opener," the parts of the apparatus are to be found in every laboratory.

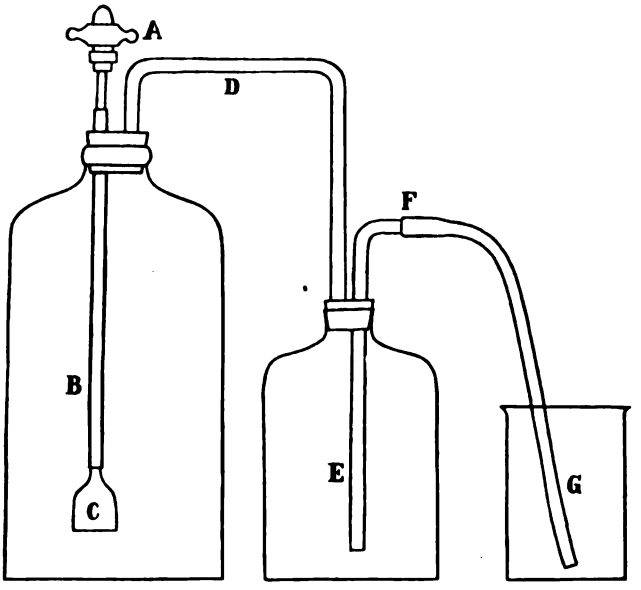


Fig. 1

B is a large bottle, the larger the better. An "acid bottle" will do, if the vertical branches of the tube D are as long as possible so as to make the space through which the carbon

dioxide has to diffuse before reaching the water quite considerable. This bottle is fitted with a two-hole stopper, best of rubber; through one hole passes the tube of the "capsule opener" A, and through the other a glass tube of wide bore, bent at right angle. A piece of rubber tubing is slipped over the lower end of the tube of the "capsule opener," to which is joined a little funnel C, made by drawing out a test tube. The object of the funnel is to allow the carbon dioxide to spread out a little on entering the bottle, and thus to decrease its speed somewhat. A smaller bottle, E (a two-liter size is good), is fitted with a two-hole stopper through which passes a wide tube making connections with B, and an L-tube over which is slipped a piece of rubber tubing about 30 cms. long. G is a beaker or bottle of about two liters capacity.

Before the demonstration is shown to the class, the apparatus should be set up all ready on the lecture table, E filled with water, which is drawn over through F, so as to fill it also with water, and the end of F kept under water in G, which is raised up and supported by blocks so that the water will nearly fill E, and yet the levels in G and E will be the same. Especial care must be exercised in pushing in the stoppers tightly and having all connections tight, as when the gas escapes from the capsule, it does so with a rush, and the pressure suddenly developed may force out the stoppers.

A capsule is weighed (to a centigram is sufficient), placed in the "opener," and the cap screwed down almost hard enough to pierce the capsule. The tip of the rubber tube in G is then pinched together with the forefinger and thumb, and lifted up so that G may be emptied and drained for a few seconds. The rubber tube is replaced in G, care being taken to keep its tip always below the surface of the water. Without delay, the cap is screwed down (the "opener" being held with the little wrench) so that the pin punctures the capsule. As the gas escapes, it displaces the air in B, which in turn displaces the water in E. In this way the carbon dioxide does not come in contact with the water at all, or, at least, not for some time. As soon as no more water appears to flow into G, which is the case in a few

seconds, it is lifted up so that the level of the water in it and in E are the same, and the apparatus is allowed to stand for a minute or so in order to bring the pressure in the apparatus to that of the atmosphere. In the meantime the thermometer (which had better be kept inside the large bottle all during the experiment) and barometer are read. No correction for aqueous tension has to be made, as the carbon dioxide is dry. The tip of the tube in G is again closed with the thumb and the finger, and lifted out. The volume of the water in G is found by pouring it out into a graduated cylinder or flask. All that remains to do now is to find the weight of the capsule emptied of carbon dioxide.

It is my practice to have the class work out the calculations for the reduction to standard conditions, which keeps them occupied, while I weigh the capsule. We then together calculate the weight of a liter of carbon dioxide from the data obtained. The values we have thus far found are 1.96, 1.98, 1.99, 1.96, and 1.98, which agree well with the accepted value, 1.97.

Care must, of course, be taken to remove all the carbon dioxide from the large bottle, before making a second determination. This is readily accomplished by pouring the gas out, as if it were water.

Although this experiment has not been put into the hands of students to perform individually, there do not seem to be any good grounds for believing that it would not prove to be a good students' experiment. The apparatus does, indeed, take up considerable room, but several of them set up on a side table would suffice for a large class. One thing that certainly recommends the experiment for students' use is the great certainty that good results can be obtained even with comparatively careless handling.

A GALVANOMETER FOR THE LECTURE TABLE.

BY C. F. ADAMS.
Instructor in Physics, Detroit Central High School.

It has occurred to me that an arrangement of a lamp and galvanometer for the lecture table, which I have used for some time and which has proved very satisfactory and convenient, might be of interest to the readers of SCHOOL SCIENCE. The galvanometer is a d'Arsonval of the earlier type, having a coil made of No. 36 wire, with a resistance of about 100 ohms. It has a plain, box-like case of walnut, with a plane glass front, 2½x9 inches, and was made in the shop connected with our laboratory. The mirror of the galvanometer is concave, about seven-eighths of an inch in diameter, and has a radius of curvature of about 20 inches. This galvanometer is sufficiently sensitive for the most delicate earth induction experiments.

In my first arrangement I used a plane mirror. A hole 2 inches in diameter was cut through the top of the table and an electric lamp fixed in position under the hole. A convex lens was placed over the hole and the light from the lamp was reflected upon the galvanometer mirror by a plane mirror placed above it. The galvanometer was so placed that the image of the lamp was projected upon a curtain or wall. While this arrangement was very good, it was not so convenient or effective as the arrangement with concave mirror described below.

In this arrangement (Fig. 1) the lamp is contained in a box about 16 inches long and 8 inches square. The plane mirror M is attached to a rod (not shown in the figure) set in the box so that it can be adjusted in height and in angle. In this way small adjustments for focusing can be made, as the distance the light has to traverse from lamp to concave mirror is changed by raising or lowering M. The side of the box is on hinges, so that it can be dropped down and the arrangement shown to the class. Two of the leveling-screws supporting the box rest

on brass plugs set in the top of the table, and thus connect the lamp in the box with the lighting circuit of the building.

The galvanometer is fastened by screws permanently in its position on the top of the box and a switch is placed on one side of the box for the purpose of short-circuiting the galvanometer and damping its vibrations, or it may be used as a shunt to render the galvanometer less sensitive. The curtain is 10 or 12 feet from

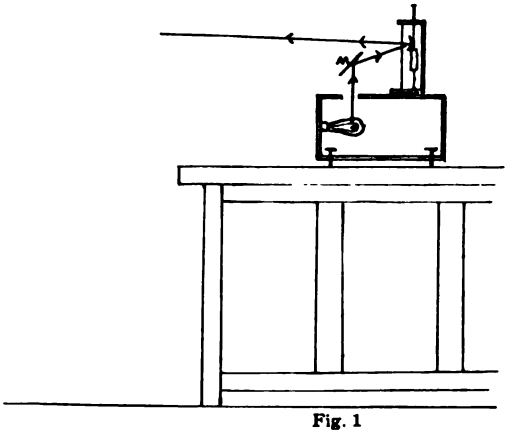


Fig. 1

the galvanometer and the image of the lamp is so bright that the room need be only partially darkened, not so much but that all that is done on the lecture table can be seen readily.

Not the least valuable feature of this arrangement is the fact that it is always ready for use. No time need be used in making adjustments. The whole apparatus needs only to be picked up, set in its place on the table and the coil lifted when it is ready for use. When not in use the coil may be held in position by two small brass rods extending through the galvanometer case, and except from the fact that the mirror is liable to fall off, the whole apparatus may be carried about by a handle on one end of the box almost as safely and conveniently as a valise.

HOME MADE APPARATUS.

BY A. C. NORRIS.
Instructor in Physics, Little Falls (Minn.) High School.

No feature of SCHOOL SCIENCE has interested my pupils more than the articles which have described some piece of apparatus which they can make themselves. They seem to get twice the profit and enjoyment out of some home made affair, although it is not as fancy or as accurate as the factory made appliance. I would like to make a strong plea for teachers to send in any ideas they have along this line. If you have any piece of apparatus which illustrates some law or principle, let the rest of us know about it. Don't be selfish.

Our physics class has made several novel appliances. One boy proposed a plan for a lung tester. It consists of a test tube fitted with a perforated cork. A piece of glass tubing is bent into a U-tube, with the short arm just long enough to pass through the hole in the cork. The long arm extends to the height of eight or nine inches. The tube is filled two-thirds full of water and the cork inserted, and when the tube is inverted the water will rise in the long arm. By slipping a short piece of rubber tubing on the long arm we have an accurate lung tester. By measuring the diameters of the tube and tubing, the number of pounds pressure can be easily computed.

Our lifting machine consists of a lever sixty-six inches long, fastened into a block six inches from one end. At the end of the long arm is fastened a fifty-pound spring balance. At the end of the short arm is a rope, which passes through a pulley fastened to the floor. In this way, the pull is always upward. We use this apparatus in a number of experiments in physiology when studying the muscular system.

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

(*Continued from page 374.*)

EXPERIMENT XIV.

Trace and learn the positions of the Celestial Equator and the Equinoctial Colure among the stars.

(A chart such as those of Upton's *Atlas,* or a planisphere, such as that of Poole Brothers, Chicago, or Mary Proctor (William Beverly Harrison, 42 East Twentieth Street, New York,) will be helpful for this. The latter planisphere can be had of the publishers at the cost of about $1.00. The atlas costs about $1.50.)

EXPERIMENT XV.

To find the rate of the moon's monthly motion.

(a.) Chart the position of the moon, some evening, with reference to any three bright stars near enough it to permit an estimate (with the aid of the hand as suggested in Experiment II) of their distances from it to be made with some accuracy, and the selected stars should be bright enough to be identifiable on consecutive evenings. Write the estimated distances from the moon to the various stars on the chart. Use a note book having a page large enough to admit of entering two or three evenings' observations on it. Each observation should be dated to the nearest minute. Estimate as nearly as possible from your charts how far the moon has moved among the stars from the first to any subsequent observation, and from this compute the time of a complete revolution of the moon through 360°.

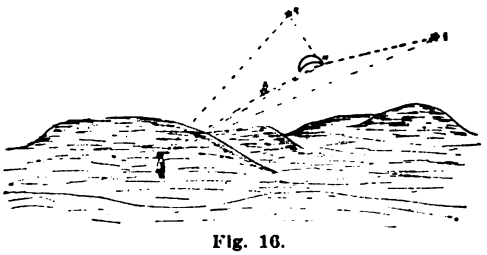


Fig. 16.

(b.) These same distances may be measured with a cross-staff, (See Fig. 15), a sextant, or with sticks.

Query: Will this give the length of a sideral or of a synodic month?

Experiment XVI.

Identify the group of stars known as the Great Dipper, or the Great Bear; the Polestar, the Lesser Bear, and Queen Cassiopeia's Chair.

(The five brightest stars of the latter make a figure resembling a poor capital W.)

(a.) Upton's *Atlas,* or Mary Proctor's planisphere will be helpful to any who may need help in this experiment. Note that the line of the two bright stars in the outer edge of the bowl, when prolonged upward about five times the distance which separates them, passes near an isolated bright star. This star is the Polestar, called Polaris, and the two Dipper stars are, from this accident of position, called the "Pointers." The Pointers are 5.4° apart and this may be used as a standard for estimating the angular distances between heavenly bodies. Other distances which are sometimes useful, are:

α to γ	Ursæ	Majoris	-	-	10°.0
α to ϵ	"	"	-	-	15°.2
β to ζ	"	"	-	-	20°.0

Having identified a number of objects on the sky and learned something of their motions relative to each other, we may now pass to a study of the motion of the sun relative to the earth.

Experiment XVII.*

To measure the altitude and azimuth of the sun.

Definitions—By the altitude of the sun is meant the angular distance of the sun above (or below) the horizon, and by the azimuth, the angle between a vertical plane through the sun and the plane of the meridian.

Construction.

Cut from inch stuff and surface two boards of dimensions shown in the cut. Square up one edge, *PN*, of the square board to an accurate right angle with the adjacent face *MNPO*.

Use.

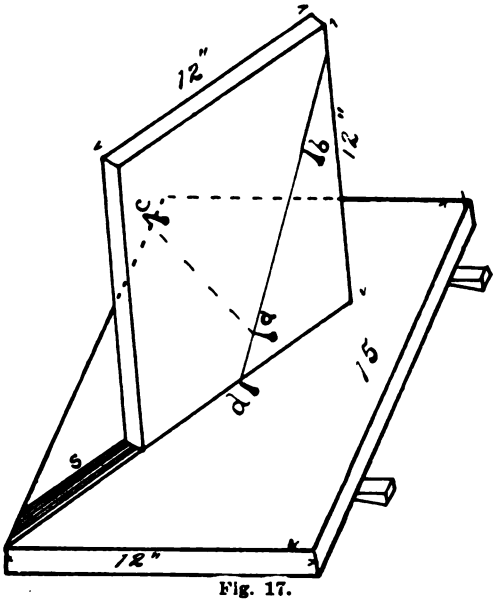


Fig. 17.

*See foot note, next page.

By the aid of the wedges place the rectangular board horizontal (indicated by pouring a little water upon it), and then set the square board edgewise upon it and edgewise to the sun in such position as to make the shadow at *s* as narrow as possible. Stick a pin in the face of the vertical board at *a* about 2 inches from the edge *PN*. Now, stick a second pin at *b* so that its shadow shall fall upon that of pin *a*. Turn the board about so that edge *OP* shall be toward the sun, and make the shadow *s* its narrowest again. Stick a third pin at *c*, as the pin *b* was placed formerly. Through the pin-marks draw the lines *ab* and *ac*, and with a protractor measure the angle *bac*. One-half of this angle will be the angular distance from the sun to the zenith for the mean of the times of sticking the pins at *b* and *c* respectively. Why?

Subtract this half angle from 90° and the difference will be the altitude of the sun above the horizon for the same time. Why?

One-half of the exterior angle *cad* will also be the altitude. Why?

If a line is drawn from the middle of one end of the horizontal board to the middle of the other and this line is placed on a meridian line (See Experiment XVIII) by drawing a line along the edge, *d*, on the horizontal board, when *s* is narrowest and measuring with a protractor the angle it makes with the meridian line, we have the azimuth of the sun also.

Experiment XVIII.*

To construct a graph for the altitudes or azimuths, throughout the day.

Let a number of students execute the foregoing experiment for eight, nine, ten, eleven, and twelve, one, two, three, and four o'clock. Work to the nearest minute. Lay off the times on a horizontal line as shown in the figure, and the measured altitudes on vertical lines corresponding to the times, and draw a continuous line through the points thus located. Drawing any horizontal line, as A B, and bisecting it with a perpendicular, the intersec-

*See Comstock's Text-book of Astronomy.

tion of the perpendicular with the curve will indicate the time by the clock used at which the sun's altitude was greatest. This is known as *apparent noon.*

By measuring the vertical distance from the horizontal line C D up to the curve we have the altitude for any time during the day. By measuring the distance to the foot of the perpendicular, we obtain the time of apparent noon, as shown by the time-piece used.

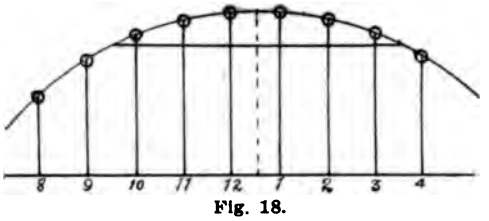


Fig. 18.

The entire curve brings before the eye the law of the sun's variation of altitude for the day.

Such curves, made at different seasons and compared, are instructive in many ways, which will readily occur to the teacher.

Experiment XIX.

To determine the form of the earth's orbit.

(a) Using the values of the solar diameter and of the differences of the sun's longitude for fifteen-day intervals, from the *American Ephemeris* (this book, which should be in the library of every high school where astronomy is taught, can be obtained from the Superintendent of the Nautical Almanac Office, Washington, D. C., by sending $1.00), plot the positions of the sun on lines drawn through a point (O) at angles (AOB, BOC, etc.) equal to the 15-day differences of longitude and at distances (OA, OB, OC, etc.) inversely proportional to the angular diameters. The first line (OA) may be taken any convenient length.

(b.) It may be instructive to make use of the apparatus of Fig. 13, using colored spectacles to protect the eyes in making the settings of the edges of the cards on the limbs, (edges) of the sun's disk. Can the measurements of the diameter of the solar disk be made with enough accuracy to bring out the law of change

of the distance from the sun to the earth from week to week, or month to month?

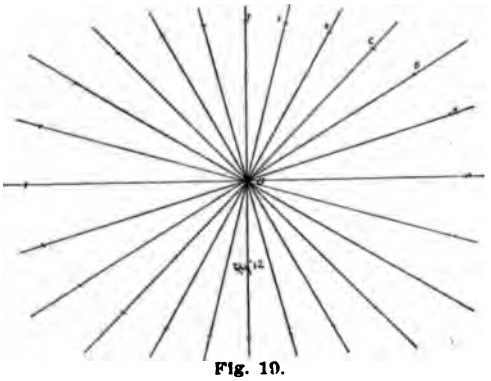


Fig. 10.

(c) The same kind of measures may be made for the moon, (See Experiment IX), using two-day intervals. Is the instrument capable of sufficient accuracy to bring out the law of the moon's changing distance from the earth?

(d.) The *American Ephemeris* data for the moon may be used in the way suggested under (a) for the sun. Try it.

Experiment XX.

To establish a meridian.

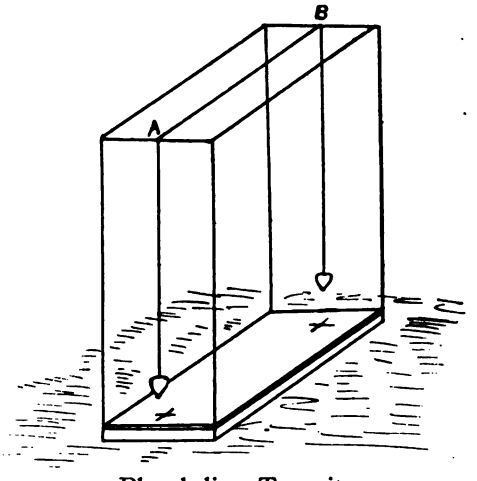
(a) Without a time-piece.

(1) By the Polestar and plumb-line.

Set four vertical poles, or pieces of gas-pipe, 6 or 7 feet tall, in the ground at the four corners of a rectangle 5 x 10 feet, the long dimension being placed approximately (by guess) north and south. Connect the tops of the poles with horizontal cross-pieces to hold them in place. Attach a heavy weight (a brick) to each end of a smooth cord, 22 to 24 feet long, and hang it over the middle of the middle points of the north and south end cross-pieces. Allow the ends of the cord to hang freely, the weights held at about the same distances from the ground, and low enough to allow them to swing freely in buckets of water if the wind is strong.

By glancing at a star atlas, it will be seen that Delta Cassio-

peia,, Zeta Ursa Majoris (the star at the bend of the handle of the Great Dipper), and Polaris, (the Polestar), are all on the same



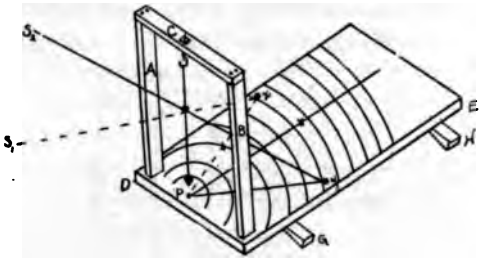
Plumb-line Transit.
Fig. 20.

celestial meridian, or hour circle. They are therefore in the meridian of any place at the same instant. If, then, an observer station himself behind (south of) the south plumb-line, and look northward at about the time either of the two first mentioned stars comes to the meridian, he may shift the plumb-line nearest him toward the right or left until this star and Polaris are just covered by the plumb-lines, at which instant the plumb-lines will be in the meridian. If the cross-pieces are now notched a little just where the cord lies, the plumb-line will always indicate the meridian by placing it in these notches.

If plumb-bobs are used, the points just beneath them may be transferred to the ground, or to a stone placed in proper position, and the meridian may then be identified at will.

(2) By observing the sun.

Suspend a plumb-line near the middle of a board on which a number of concentric circular bands, alternating black and white (black lines between white spaces will do), struck with the point *P* of the board just beneath the plumb-bob as center, and provide the plumb-line with a sliding bead. (See Experiment XXV.)



Plumb-line Gnomon.
Fig. 21.

Note the point (x) of any circle where the shadow of the bead crosses it in the morning, and the point (y) where the same circle is crossed by the shadow in the afternoon. Connect these two points with the center of the circle and bisect the angle between the connecting lines. The bisector is in the meridian (if the board *DE* has not been moved meanwhile), and the line may be readily transferred to and fixed upon the ground.

(b) With a time-piece.

Obtain the correction of the time-piece by methods to be given later, and compute the time when the star should be on the meridian. If the time-piece is rated to keep sidereal time, the right ascension of the star, obtained from the *American Ephemeris,* will be the correct time when the star crosses the meridian above the pole (upper culmination), and this right ascension increased by 12 hours will be the correct time of lower culmination.

If the time-piece keeps mean solar time, the sidereal time can be found approximately by adding to mean solar time 2 hours for each month, and 4 minutes for each odd day, since the Vernal Equinox (March 21st). The table at the end of the *American Ephemeris* will make possible a more accurate determination of the sidereal from the mean solar time, and vice versa. After the sidereal time has been determined, it may be compared with the right ascension as before. The difference is the *correction* of the time-piece, + if it is slow, or — if fast.

(*To be continued.*)

Metrology*

PARTIAL USE OF THE METRIC SYSTEM THIRTY-FIVE YEARS AFTER LEGALIZATION.

[CONTRIBUTED.]

(*Concluded from page 382.*)

The following sentences are quoted from the *American Manufacturer:*

"The metric system is making some headway among American manufacturers engaged in the export trade. This is especially true of machinery builders. It will continue to make headway according to the increase of our exports."

* * * * * * * * * *

"There are firms that have adopted the metric system for their export business. They do not seem to be suffering from the effects of having two sizes of templates and dies for their plants. They are filling orders for export and are teaching their workmen the use of the metric system in so doing."

The incongruity of having two sizes, whether there seems to be suffering from the effects or not, continues until the superseding in domestic trade also of old weights and measures by metric. A similar remark may be made in regard to United States importations of bottled goods, textiles and other manufactures from foreign countries where the metric system is in use.

Consider bodily measurements, etc. The stature and strength of athletic young men in the colleges in different parts of the country are recorded in metric units and are published; but sometimes the newspapers, instead of recognizing the kilos, call them "points." Dimensions of statuary, etc., have been given metrically in the reports of the Boston Museum of Fine Arts regularly for many years. There is great convenience in measuring the clothes, as well as the body, in centimeters, not requir-

*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

ing fractions; and among men's furnishing goods some suspenders may be found with the length marked upon them in centimeters; but there remains in principal use for the measurements of tailors and dressmakers, and for sizes of such things as gloves and hats, the old unit with the ubiquitous fraction.

Consider applications of science. The metric system has been thoroughly adopted for scientific research upon all subjects and for the diffusion of scientific knowledge by publications and educational institutions. The extent of its use for instruction, laboratory supplies, apparatus, etc., is enormous; yet when scientific knowledge is utilized in technical work or for commercial purposes it often happens that old units of measurement are employed; so we have the incongruity of preaching one thing and practicing another, of producing certain effects with one measure in investigation and with another measure in business. Such complications are now a characteristic feature in our literature, the discussions of our professional organizations, reports of committees of research, periodical publications, or books of the day. Similar complications are common in shops, offices and practical work, a fact so familiar as to require little illustration. Fineness of sand is expressed by the millimeter, and fineness of the sieves and screens for it by the number of meshes per inch. It is by the cubic centimeter of water that the number of bacteria are reckoned in biological examinations, but, rather than say so, men otherwise intelligent have sometimes disguised it for the popular mind as "thimbleful." Opticians have adopted metric measure, and, besides whatever else they have done in regard to their apparatus and accessories for microscopy, etc., they have a metric basis for expressing the power of lenses of spectacles. Their "dioptrics," depending on the focal length in meters, are found in the optician's price-list; yet it is not uncommon to express the diameters of lenses in old measure, which may be found even in the same catalogues that give generally the metric system.

It is needless to marshal further evidence. The cutting off of the dog's tail is by centimeters, so that the tail may continue in some measure to wag the dog, as long as he likes to have the operation protracted.

NOTES:

Progress of the Metric System.—The following are some indications of recent progress in metric reform:

1. The British consul at St. Petersburg writes that "the Russian government has in principle adopted the metric system, but no definite decision has yet been arrived at in respect to its compulsory use in Russia."

2. The Committee of the Associated Chambers of Commerce of Great Britain has adopted the following among other resolutions: "That after considering various suggestions this Committee is unanimously of opinion that the Chambers should unite in urging upon the Government the compulsory adoption of the metrical system of weights and measures, leaving matters of detail to be considered later."

3. Secretary Johnson, of the Decimal Association, writes from England: "Our colonies are displaying much more interest in the question, which is well to the front in Australia, Canada and even in Cape Colony in spite of the war."

4. United States Consul Hill reports from Amsterdam, Sept. 7, 1901: "The necessity for United States manufacturers to adopt the metric system in foreign trade becomes daily more imperative."

5. Representative J. F. Shafroth has introduced into the national House a bill for the compulsory use of the metric system by the various Departments of Government—similar to his bill in the last Congress.

6. The American Metrological Society has just appointed a Committee on Legislation, consisting of Professors Simon Newcomb, S. W. Stratton, J. H. Gore, Dr. W. H. Seaman, Supt. O. H. Tittman and ex-Minister John A. Kasson, to confer with the House Committee on Coinage, Weights and Measures, with reference to the passage of a metric bill. This Committee, from its recent conference with the Postmaster-General, reports that there is "every reason to believe that he will look with favor upon the use of the metric weights in his Department."

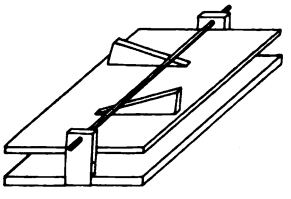
R. P. W.

Notes.

BIOLOGICAL.

Primula abconica is very suitable for starch-making in the leaf to use in place of *Nasturtium* in the experiment given in most text books. It can be had in greenhouses and is even more efficient than the latter plant.

Central High School, Detroit. BERNICE HAUG



A Simple Plant Press.—To the ends of a 1¼-inch board of suitable length and breadth two upright pieces of board are nailed. Near the tops of these bore holes directly opposite each other and put a cylindrical stick (broom stick) through them, or nail a piece of narrow board, beveled on the under side to fit a pair of opposite wedges, to their tops. Cut a pair of strong wedges from an inch and quarter board, about one inch less in width than the space between the stick and the base-board. A board small enough to go between the upright pieces and cover the base, completes the press. Arrange the specimens on the large board and drive the wedges beneath the stick. As the specimens dry the wedges are driven in deeper.

Central High School, Detroit. BERNICE HAUG.

Simple Method for the Examination of Blood.—It is not difficult to get a bit of human blood by twisting a handkerchief tightly around the thumb, bending it strongly and pricking with a sterilized needle in one of the creases. But to keep the corpuscles from shrinking has been by any ordinary means, except the warming stage, an unrealized desideratum. After trying various ways I have found that mounting in saliva will keep the majority of the corpuscles in good form and generally show the rouleau pattern of the red ones, while the white ones retain a spherical form.

To avoid getting more air than the saliva contains it is best to put the saliva on the surface to be pricked so that it will mix with the escaping blood.

Sealed by vaseline or paraffine around the cover-glass, such a mount may be used for several hours.

L. M.

The Cleaning of Slides, especially of a large number, is an irksome task. The drudgery of this kind of work may be considerably lessened by the use of the following simple devices, and the rapidity with which slides can be cleaned is much increased by their use. A base board about 12 cm. in breadth and of any convenient length and thickness has a cleat about 2 mm. thick and a centimeter or so wide tacked along one edge, and a similar cleat tacked at one end so as to project at right

angles 7 cms. from the first cleat. Two similar cleats are fastened together at right angles by cutting their ends off at an angle of 45 degrees and tacking them to a piece of wood at the corner so that the lower surfaces of the cleats are in the same plane. The dirty slides are placed side by side along the cleat fastened to the base board, and the detached right angle piece set upon the board so as to hold the slides in place. By exercising some little pressure against the side and end of the slides, the device may be turned upside down without the slides falling out of place. The slides thus held firm are scrubbed with soap (sapolio) and water, the slides turned and their other sides cleaned in a similar manner. Time may be saved in the turning of the slides by having a second base board provided with cleats as above described, placing it over the slides and inverting. The slides will thus be transferred to the second board with their unscrubbed surfaces uppermost. After these have been cleaned, the slides are thoroughly rinsed in water, it being advantageous to invert them once or twice by transferring them from one board to another. The slides may be rapidly dried as follows, the glass being also left in a clean, highly lustrous state: A coil of spring brass wire, about 2 cm. in diameter and 10 to 12 cms. long, is prepared (the spiral springs used to hold a collection of penholders answers, if the wire be stiff enough) and the ends of the slides inserted firmly between the consecutive coils. The slides and coil are then soused in clean alcohol contained in a wide, shallow jar or dish and hung up to dry.

Correspondence.

EDITOR SCHOOL SCIENCE:

The words of Dr. Ingerson in the November number (page 291) ought, in my opinion, to be taken very seriously to heart by every true physics teacher, and much thought given to ways of remedying the evils there arraigned. Electricity and magnetism are, it is true, fascinating subjects to the average pupil, and his interest is aroused by coming into more direct contact with things about which he has been more or less curious from his early grammar-school days. But, as Dr. Ingerson says, "we need to have a care lest our class-rooms degenerate from places of education into halls of diversion and amusement." The culling out of the hard things in the study of elementary physics, the avoiding of everything that is dry and dis'asteful to the pupil is a practice which seems to be on the increase, and it is high time that a halt is called. The mere acquisition of facts is not what the study of physics should require of the learner—that is perhaps the last of its requirements. What physics should give is power—power to think, to do, to act.

A young man presented a note-book on physics as one of his credentials for entrance into a university. It was neatly written and showed that the candidate had considerable ability in observation and facility of

expression. The contents pertained almost wholly to the subjects of electricity and light. On examination, the candidate for admission showed an almost total lack of comprehension of the simplest notions of mechanics. He had, indeed, made an induction coil and a telescope, but the power acquired thereby had been rather that pertaining to the artisan than to the scientist. His work in physics had resulted in comparatively little benefit to himself, although he professed great interest in the subject. The fault did not lie with him, but did lie with his teacher. What is to be done with cases like this, which are by no means uncommon?

The bother about the study of elementary physics is that the hard things come first. In a year's course the fundamental subject of mechanics takes up, or at least should take up, the first four months. Teachers are prone to avoid this *absolutely necessary* work in mechanics, or at least to slight it. And yet it is fundamental to the whole science. A good grasp of the principles of mechanics once obtained and the rest of the work is comparatively easy. Pupils, it is true, get a distaste, perhaps, for the whole of physics from the preliminary part of it, but is it good pedagogics or good science to avoid the distasteful things? Keep the pupils' anticipation agog as to the interesting things that are to come after the drudgery. Geometry is distasteful to most students at first, but still they learn it, and in the good old way.

Is mechanics harder than geometry? I think not, and pupils can be led to get even more interest out of it than out of geometry. Do not cut out as much as possible of mechanics but rather increase its amount for the profit to the student will be that much the greater.

The *practical* facts of geometry are commonly known by students before they study geometry, and yet they plod away at the subject for a year and why? The only answer is, to acquire power. And so it should be with physics. Make physics a "powerful" study.

X

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

36. What is a good list of about a dozen quantitative experiments suitable for a class in high school chemistry?

37. What cases of chemical arithmetic should a senior class in high school be required to master?

38. Which is considered to be of more pedagogical value, a half year of botany or a half year of physiography?

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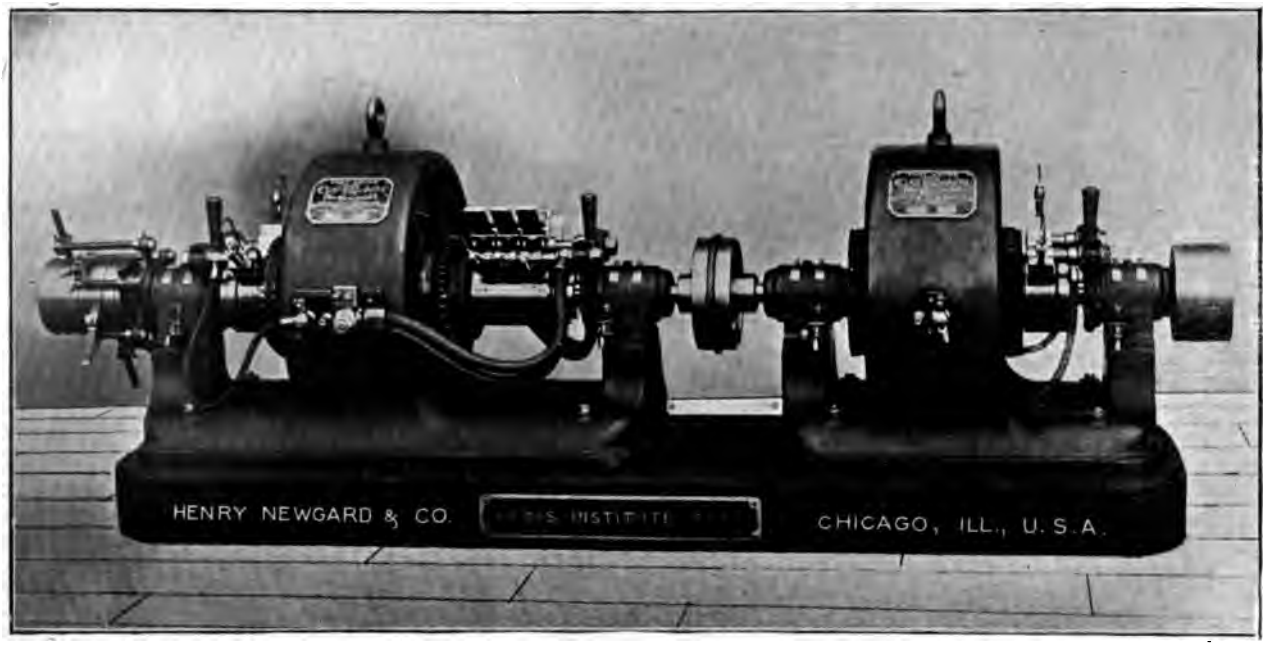

THE CARMAN SCHOOL TRANSFORMER

CATALOG ON APPLICATION.

School Science

VOL. I] FEBRUARY, 1902. [No. 9

CLASSIFICATION AS AN ELEMENT OF EDUCATION.*

BY N. A. HARVEY,

Head Critic of Chicago Normal School.

I assume as the basis for this discussion, that the teaching considered in this paper is educational in its nature rather than professional. I mean by this that it shall be for the ultimate purpose of training the mind to do better what all minds can do in some degree, rather than to accumulate a fund of information to be used in the practice of a profession. The psychological movement of the learner rather than the logical development of the subject is the thing that is of the first importance, and is the chief factor in determining the method to be employed.

Permit me also to state that in all my illustrations I shall have in mind the teaching of science in high schools. If the teaching of scientific subjects in colleges and professional schools were to be considered, the illustrations and basic propositions would need very considerable modification.

The greatest contribution of science to education is the scientific method. The scientific method is not a method of teaching, but it is a method of thought, and is capable of universal application. It is called the scientific method because it has been developed chiefly in scientific subjects by scientific men. Its importance is so great and so fully recognized that we are continually finding the scientific method applied to subjects formerly considered most remote from scientific facts.

*Part of a Paper on "The Study of Types, Its Significance and Its Application," read before the New York State Science Teachers' Association, December, 27, 1901.

In the scientific method of study, an individual is the first thing to be considered. From this fact the scientific method is sometimes regarded as an example of induction. In reality, the scientific method is quite as much deductive as it is inductive, but the starting point is the same as in a case of pure induction. This individual which is taken as the starting point may be called a type, since it always embodies the characteristics of the group that is founded upon it. A type may, however, mean much more than the individual that is studied. It necessarily involves all the characters that enter into the concept of the class, but it should be one that contains the average characters of the class. Individuals of the same kind are not all alike. Variations occur that make them individuals. These variations are quantitative in their nature, and in some individuals are much greater than they are in others. In any group of individuals that are combined into a class, there will always be extremes of variation, and an average point or norm, from which variations occur. In the vicinity of this norm will be found the greater number of individuals that constitute the class. It is this average, this point of departure, this possessor of common characters in the least variable degree that may stand for the type of the class. It will be seen, then, that the selection of an individual to stand as the type of a group is a matter demanding considerable care. It certainly would be very unwise to select as the type for study one of the most aberrant or divergent forms in the group.

It is evident that the selection of an individual to stand as a type will depend upon what it typifies. An individual is not a type unless it stands in the mind for a class, or stands as the representative of a group, all of which have common characteristics. We come at once, then, to classification as an element in scientific study. Classification is implied in almost every operation of the mind above the simplest. It is implied in every act of judgment. Whenever we use a common noun we make use of classification or its results. Every catalogue, every index, every table of contents, the arrangement of our houses and of our streets attest the necessity we feel ourselves under for classifying objects. It is a universal process, and is common to all human

minds. It is this process of classification that constitutes science and renders possible scientific knowledge.

Classification of a series of objects is the ideal or the actual arrangement of those together that are alike and the separation of those that are unlike. It enables us to do two things: First, it enables us to retain in mind the characters of many objects at once, as well as to infer from things known, unknown correlative characteristics. It is a labor saving process. It conserves mental effort, and this economy of mental effort is perhaps the most important principle in education. It is the thing that largely constitutes the difference between the mind of great power and one of little power.

But classification does something more than this. Classification discloses to us the correlations or laws of union of property and circumstances. It is only when we make a proper classification that these laws appear. We are inclined to think that for every series of objects there is one system of classification that is best, which we call the natural system, and much energy is devoted to the discovery of that system. The so-called natural system of classification in animals and plants is a genealogical system intended to show the relationship by descent of the individuals classified. This system is not yet complete. We do not know enough about animals and plants to adjust them satisfactorily in their places. But there is no question that the arrangement of organized beings in the natural system of classification has been productive of the greatest good in the development of our scientific knowledge, and in disclosing some of the profoundest and most far-reaching truths.

But the natural system of classification is not the only one that may be used to advantage, nor the only one that is still employed in classifying animals and plants. Other systems of classification disclose other laws than those of descent. We still have, and we still need, the classification of geographical regions, of temperature zones, of life habits, of geological horizons, of physiological functions. Each of these classifications is necessary and will always be used because each discloses natural laws that constitute an essential part of scientific knowledge.

I think I do not overestimate the importance of the study of classification as an element in education. There are certain elements of dynamic thought involved in classification that are positively fundamental. Somewhere in the life of a student there must be a place in which the processes and methods of classification are consciously worked out. If this can be done in one or two subjects, the principles of classification can be applied to other subjects and be used as a tool to make further acquisitions of power in other directions.

Botany and zoölogy are the classificatory sciences *par excellence.* Here the principles of classification have been worked out with a minuteness and fullness of detail observed in no other subject. Here, if anywhere, the student must get his knowledge of those principles. In my opinion, botany and zoölogy must rest their claims for introduction into a course of study largely upon the fact that they are classificatory sciences, and any attempt to substitute some other element than classification as a basis for work in these subjects is to discard an element of greater importance for one of a less.

I am not unmindful of the fact that both subjects involve many departments in which the element of classification is not the conspicuous process. Such are the departments of physiology, histology, cytology, paleontology, embryology, ecology. Each of these may be taken as a basis of knowledge of animals and plants. My contention is that in an elementary course, it is highly injudicious to make anything but taxonomy the basis of the work. The other departments are tributary to this and should be so recognized. They are highly specialized departments, and can scarcely be studied in their full significance without some knowledge of the taxonomic relations of the forms used as types. I would make taxonomy the basis of the work and group around it the essential features of all the other departments, not by any means omit them.

Just here I should like to pause long enough to comment upon the value that exists in systematic work in botany and zoölogy. It is a kind of work that has of late fallen very much into disfavor, and very properly, too, in consequence of the great abuse to which it has been subjected. The marks that are used to dis-

criminate genera and species are apparently so trivial that they seem ludicrous. I merely wish to suggest that the variation in physiological function and life habits are usually much more pronounced than are the morphological differences that can be quantitatively stated and used to discriminate species. Even among individuals of the same species such variations of personality occur that we need to study many individuals of the same species in order to obtain an insight into the psychology of species. Also I would suggest that all the most delicate work of the embryologist, the histologist, the ecologist, everybody who contributes to the knowledge we possess of an individual of a particular species only helps us to arrive at a better understanding of the relationships that exist among the various groups of animals and plants, which is precisely the thing that the systematist attempts to do in a rough and ready way.

THE EDUCATIONAL VALUE OF PHYSICS.

BY WILBUR A. FISKE.

Instructor in Physics, Richmond (Ind.) High School.

The educational value of any subject certainly depends upon what we understand to be the purpose of education.

If, according to Plato, "It is to give to the body and to the soul all the beauty and all the perfection of which they are capable," or, according to Stewart Mill, "It includes whatever we do for ourselves and whatever is done for us by others for the express purpose of bringing us nearer to the perfection of our natures," or if, as Herbert Spencer would put it, "Education is the preparation for complete living," then physics, we maintain, will always command the respect of educators for the powers it possesses in fulfilling the requirements of these different views.

If the purpose of education is to prepare a boy or girl to make a living, then the study of physics, scientifically pursued, is not an unprofitable outlay of time. Or if it has for its aim something higher and nobler than this—the quickening of the latent intel-

lectual and even the moral powers—we still maintain it will stand out prominently among other subjects in accomplishing its ends.

While much has been said on physics, it is not by any means a wornout subject. It is of too recent development for that. Although the subject has for centuries been taught in the schools, yet, from a scientific standpoint—the only one from which we can in this day consider it—its birth dates back but a few decades.

A quarter of a century ago scientific physics had but little place in our schools. Since that time it has been placed in the front rank along with other strong subjects of the curriculum. In many cases other work has been cut down in time or wholly removed to give place to physics, the latter having been recognized as of great value from a cultural point of view, and therefore an important feature in education.

The object of physics as taught in the schools is not to place the individual in possession of a fund of knowledge in regard to facts and theories. It is of little consequence in later years that one has by experiment proved the laws of the pendulum, or that a certain fixed numerical value represents the latent heat of steam. These facts and figures will fade away as scaffolding from a building, but that which inevitably follows as the result of working these things out remains to the end the beautiful and enduring structure.

The true purpose of any subject of study, then, is not to impart facts alone, however valuable these may be, but to furnish power—a mental power that will stand by and aid one in fulfilling the important relations of life.

In the acquirement of this power, physics, we hold, is of pre-eminent value, from the fact that it affords such a wide range of culture. While there is a supreme beauty and pleasure to the lover of science in knowing the cause and effect of natural phenomena, yet the great value of this subject does not lie here, but is found in the power it possesses of developing the faculties of the mind.

If rightly pursued, physics is vigorous in the demand it makes for a strict habit of observation. It is not a superficial observation

that is demanded on the part of the subject, or fostered by a study of it, but an observation that is persistent. To become a good runner, one must run, or a good singer, one must sing. Equally so, to become a good observer, one must observe—to see things as they are, and be able to describe them in their minutest detail. Such an observation as this is fostered by a study of physics.

It is remarkable what little power the average boy or girl seems to possess in the way of observation when entering this domain of science. They seem to be utterly helpless to see, even approximately, what is before their eyes, and then describe accurately what they have seen. This, we are led to believe, is in a large measure due to a neglect of earlier scientific training.

A training of the observation cannot begin at too early an age, and there is hardly a subject more potent in the development of this faculty than easy lessons in science. Neither should this training be relaxed at any time, but should be pursued vigorously and systematically throughout the earlier school years of the child, thus preparing him to fully appreciate and grasp with firmer hold the more intricate principles and problems of the higher sciences.

The acquirement of this power of observation is greatly accelerated by means of object-lessons. Less study about things and more study of things themselves. "Object-lessons," says Spencer, "should be extended to a range of things far wider and continue to a period far later than now. They should not be limited to the contents of a house; but should include those of the field and of the hedge, the quarry and of the seashore. They should not cease with early childhood, but should be so kept up during youth as insensibly to merge into the investigations of the naturalist and the man of science."

Physics also, if rightly pursued, insists upon the closest application of thought. Uninterrupted thought on the part of the student is demanded for a perfect comprehension of the principles which the subject involves. If these demands are carefully obeyed a mental power not before possessed will surely follow.

The principles and laws of physics have been established only by men of genius, and if carefully worked out to a full under-

standing can not fail to give an increasing power in fixing the mind upon a given question, and holding it there until a definite end is reached.

This power of mental concentration is one of the most valuable acquirements of a lifetime, for mental concentration leads to clearer thinking, and clearer thinking leads to a more perfect expression of thought in words, while the expression of thought in well selected words is a certain mark of culture, and any subject of study that will aid in the smallest degree to confer this gift upon a boy or girl should receive a good share of time in any school.

A study of physics also awakens a spirit of investigation. There are exceptions to this, however, it might be said, yet I have learned from experience that a bright, active boy—and there are a few such in every school—is not content to loiter lazily along the border line of this great field of science, but he has a constant desire to push out and make short excursions alone for the purpose of investigating something that has been suggested to him by some other thing he has previously done. This may be boyish investigation, but, nevertheless, it is investigation, and shows that he has received an impetus in the right direction, which, if rightly encouraged, will lead to greater victories.

The value of all this does not lie in the fact alone that additional knowledge is gained, but the great acquirement is the power which comes by seeking these things out; by verifying principles and proving established laws.

Again, physics cultivates the imagination. By experimentation certain facts are discovered. In order to account for these facts, it is necessary in many cases to imagine a cause, which, if it existed, would readily produce such results. This leads to the establishment of a theory the apprehension of which greatly accelerates the power of imagination. It is not necessary that this theory be established by the student. Indeed, such a thing would be impossible; but, if he is alert to his task, he will actually live over again, in a great measure, the whole mental process that was evolved in leading up to this end.

Another important educational value of physics is the part it performs in the development of the power to reason and judge correctly. Each principle and law of physics is designed to cultivate and train these faculties of the mind. Each laboratory experiment worked out by the student in the verification of these principles and laws should involve a process of sound reasoning, which, if carefully and persistently followed to an end, will necessarily result in acquired power along these lines. This process of reasoning must, of course, lie within the compass of the mind dealing with it; but it must be reasoning, and not seeing only. It must insist upon that kind of mental activity that will accomplish something, and not upon that sort which gives the mind unbridled freedom.

I am convinced, from my own observation, that any other kind of laboratory work is only a waste of time, energy and money, and will certainly not result in the greatest good that is possible to be obtained from this phase of the subject.

A study of physics, as well as other branches of science, will afford an excellent moral training. It is, indeed, no panacea for human depravity, but who can possess the true scientific spirit, the spirit of unselfish, honest and thoughtful truth-seeking, and not experience a general moral uplifting?

While this scientific spirit may not be possessed in a very great measure by the beginner in physics, yet it is here that the germ which finally develops into the finished product, manifests its first signs of life. A comparative study of biography will show conclusively that immorality has not held much prominence in the ranks of scientific men, far less than among men whose lives have been devoted to literature and art. These lines of thought may possibly arouse the baser passions, but scientific truth is never impure. In many other things there is a tendency to accept, without questioning, whatever has been established, which in the end must necessarily cause an undue respect for authority. A thing is true because somebody says so, or because the rule directs that it be worked out in that manner, and the pupil, in most cases, believes it without ever asking why.

It is not so with science. The mind that has been trained by a scientific culture takes nothing for granted; in fact, is asked to take nothing for granted, but seeks to test the truth of all things. The confidence and trust in one's power, produced in this way, establishes an independence which is a most valuable element in the building of a character.

"The first condition of success in scientific pursuits," Prof. Tyndall has said, "is patient industry and an humble and conscientious acceptance of what nature reveals; an honest receptivity and a willingness to abandon all preconceived notions, however cherished, if they be found to contradict the truth."

Dr. Morton, of Stevens Institute, in answer to the question what lines of study most tend to develop intellectual honesty in the minds of educated men, has said: "Those studies which involve the explanation of the laws and facts of nature, physics, chemistry, natural history, mechanics and the like, deal with immutable facts, and the student of these has no use for the sophistries by which he might mislead himself and others."

Again, a study of physics, or any other branch of science, brings the student into closer communion with men of genius—men who have spent their lives in the intellectual advancement of mankind, and whose pulse-beats have many times been quickened by the sudden revelation of some long sought truth. A careful study of the life of Galileo, Newton, Faraday, Lavoisier, Dalton, Agassiz, Pasteur, and a score of other men of science, has often inspired within the earnest student a feeling of respect and noble emulation.

We have now spoken of the many advantages gained by a study of physics. These considerations belong to the pupils' side of the question. The methods employed to bring about the best results, to furnish the broadest culture and the best equipment for the student to fulfill the purpose of his life, is the side with which the teacher has most concern. The relation between these two - method and results obtained—is one of the vital questions, for it is certainly true that the amount and quality of the culture obtained from this branch of science, as well as any other, de-

pends in a great measure upon the methods employed in conducting the work.

I am convinced of the fact that the laboratory, when properly equipped and managed, is the great field of inspiration, even to the high-school student.

There are some, however, indeed, there may be many, who never catch this inspiration, although it may be most contagious. Yet this need not be a distressing feature, for there are many boys and girls in the schools to-day who would not even catch the measles or mumps if at first they were compelled to work out a formula for the purpose of demonstrating the progress of the disease.

The work done in the laboratory, I am further convinced, to produce the best results and to command the highest respect, should be quantitative in its nature.

It is unnecessary, in this day of laboratories and the kind of work done therein, to explain what that means. We are all familiar with the term. It is likewise unnecessary to state that every quantitative experiment is qualitative also, and that the latter precedes the former in the development of the experiment.

If we were to stop, however, with the completion of the qualitative phase, the greatest good, we maintain, that is possible to be obtained from the experiment is lost entirely to the student. In view of this it is the duty of the teacher of this subject to see that the proper kind of work is mapped out for the laboratory course, and of the assistant, or whoever may have the work in charge, to see that each pupil works his experiment in a quiet, thoughtful searching manner, making in each case a sharp distinction between what he does, the observations he makes, and the conclusions drawn from observed phenomena, or the relations existing between data obtained in the progress of the work.

The note-book, which naturally comes in at this point for consideration, is also of great educational value to the student. It compels him to put into writing the thoughts that are in his mind. It aids him to a clearer expression of thought; it trains him with increasing thoroughness in scientific composition; it

impresses more firmly upon his mind the facts he has learned in the development of the experiment; it enables him to acquire more systematic methods of doing things, and, as the note-book should never, except on rare occasions, be taken from the laboratory, it teaches him to do things now, and not wait until to-morrow or some other convenient time.

To these ends it must be insisted upon that the notes be neatly written, clear, concise and simple, containing only that which is necessary to make them complete, and finally absolutely correct, or as nearly so as the manual skill and mental caliber of the student will permit.

The classroom is the second field of operation, and one to which no little importance is attached. Although the work here is in general of a different nature, yet this is the time and place for a final rounding up of the laboratory work, for the purpose of ascertaining to what extent it has been comprehended by the pupil, and to obtain a measure of the value it has been to him.

While the laboratory, as previously stated, is the place for quantitative work, in the classroom that of a qualitative nature should prevail. An occasional quantitative experiment before a class is to be commended as a valuable thing, yet the very nature of such work requires time and a close range, and should, therefore be left to the laboratory, where it can be conducted in a much more satisfactory manner. There are always objections advanced that rigid laboratory work is unattractive to the pupil, and will cause him to acquire a dislike for the subject. That it is the phenomenal, the wonderful, the awe-inspiring that lends enchantment to him and leads him on in the work. Experience has shown conclusively that such is not always the case.

There is no reason, it seems to me, when physics is in the Junior year, when the candidate for the subject has had a year and a half of algebra, a half year of geometry, and in many cases is carrying the subject of trigonometry along with that of physics, why the subject, although largely mathematical, together with the manual work it requires, in which he always takes delight, should not be most attractive to the average student in this branch of science.

The work on prepared lessons in the classroom should be illustrated to the fullest extent by qualitative experiments. And here is where the student gets the phenomenal side of the subject. His responsbility, however, should not end with merely seeing these experiments performed, but to obtain the greatest educational value from this source as well, he should be required to make the same careful and complete record of the most important experiments, at least, in this case, as he does of those he has worked out by himself in the laboratory.

I have made some experiments along this line with my classes, and have found in every case that when required to make these records in the manner here indicated they are certain to see more, and to see it more correctly, to determine closer relations, to draw more accurate conclusions, and to describe with greater ease and accuracy at any time all that took place in the progress of the experiment. The retention of the facts and principles of the text, and the lessons obtained from the experiment, are the things to be desired, and any method that will make deeper impressions and more lasting notions, if they be correct ones, will necessarily result in the greatest educational value to the student.

ON THE TEACHING OF PLANT PHYSIOLOGY TO LARGE ELEMENTARY CLASSES.*

BY W. F. GANONG,

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In the introduction to his collected essays, Weismann says: "The history of science proves that advance is not only due to the discovery of new facts, but also to their correct interpretation." I think it is equally true that the history of science is now showing that advance is due not only to the discovery of new facts and their correct interpretation, but also to their utilization. The old-time toast, "Here's to the latest scientific discovery; may it never do anybody any good," albeit said in humor, expresses a sentiment

*Read before the Society for Plant Morphology and Physiology, at the Second Columbia Meeting, Jan. 1, 1902.

now becoming obsolete. Today we are offering this substitute: "Here's to the latest scientific discovery; may it elevate the condition of our fellow men." Of the many lines in which this humanitarian utilization of scientific research is vigorously progressing, two are of direct concern to us; first, such activities as are conspicuously displayed by the Department of Agriculture, and, second, the introduction of science into general education. It is within the province and, I take it, is the duty, of this society to promote, in these directions, the utilization as well as the acquisition of knowledge.

That the study of plant physiology is rapidly rising in educational favor, there are many evidences. The newer elementary text books, without exception, give much, perhaps ample, attention to it—an attention, it may be noted in passing, which is often better in the spirit than the performance, for not a few physiological errors are surprisingly current. Again, the Standard College Entrance Option, formulated by a committee of this society, lays much stress upon this subject; and it is notable, as shown by the report of the committee in charge of it, that of all the criticisms of the Option which have been received, not one takes any exception to the physiology. This increasing prominence of plant physiology in education is no doubt due not only to a growing appreciation of its inherent educational merits, but also to an awakening realization of its superiority as a physiological foundation for a biological education, and of its pre-requisiteness to further accomplishment in economic and ecological investigations. That it does not advance still more rapidly is due to two obstacles, both more seeming than real. First, there are the difficulties and the expense of much of the manipulation; these, however, are being rapidly minimized, if not removed, by the many contributions to the simplification of methods and appliances now appearing. Second, there are the difficulties of teaching the subject properly to large elementary classes; this is a real difficulty, but one less formidable than it appears, as I hope the following brief observations will show.

It is agreed that, in elementary work, no more is needed than from eight to twelve good,—that is, conclusive and practicable,

—experiments upon the most fundamental subjects, photosynthesis, respiration, osmotic absorption, etc. Now, the ideal plan would be for each student to try for himself each one of these experiments. This is the logical end towards which we should work; and I have no doubt that, as appliances are simplified and improved and become purchaseable at a fair cost from supply companies, this method will gradually come to prevail in the best courses. The idea of providing a laboratory with the necessary equipment may appear formidable at a first glance, but so, many years ago, did the idea of equipping laboratories with sufficient microscopes to supply one to each student, yet this is now a matter of course in good institutions. Like the microscopes, the physiological appliances, once obtained, may be used for many years. The time has not yet come, however, for so complete a fruition of our hopes in this direction, and for the present some very much simpler plan must be adopted. We all agree that mere lecture demonstrations of the subject, though far better than no treatment of it at all, yield results greatly inferior to those obtained from that individual, personal contact with things and phenomena which can only come from the student having an actual part in the proceedings. To accomplish this with my own classes, of from forty to eighty students, I have tried two methods. The earlier was to set up the experiment carefully for the class, place it in the laboratory with full explanatory notes and diagrams, etc., and expect students individually to observe and record results as if the experiment were their own. This I have abandoned because most students did not gain a clear idea of the significance of the different features of the experiment, particularly the reasons for parts of the manipulation. The second plan has worked very much better, partly, no doubt, because it catches and holds their attention better than the former plan. With the entire class assembled, and only the bare materials for the experiment upon the table, I try first to make sure that the importance and general bearing of the problem to be studied is clearly before them; in fact, I try to make the experiment seem, as it really is, not only a logical but a necessary step in their progress. Then I set up the experiment from the very beginning, explaining the reason for each step and

for the use of each piece of apparatus, the action of each chemical and the physical principles involved. The students follow, asking what questions they wish, making full notes and sketches, etc. The completed arrangement is then placed in the laboratory, and each student makes individual records of the observable results. When the results are complete, or when the result depends upon some special test to be applied, the experiment is again brought before the class; the tests are applied and results discussed. A mimeographed synopsis of the experiment, indicating the theory of the method, and giving such statements of fact as are essential to a full grasp of the subject, is then supplied to them, and from these various sources they are expected to prepare a synoptical, illustrated exposition of the object, method, results and bearings of the experiment. This is then examined and criticised like any other part of their work. The results are not ideal, but neither are the students, though upon the whole both are pretty good.

This mention of students leads me to add a word upon this phase of the subject. A serious obstacle in the way of all such studies as are here referred to is the ignorance of most students (particularly college students) not only of the rudiments of physics and chemistry, but also of the commonest facts and phenomena of the world about them. Combined with this, is a distrust of their power to use such knowledge as they possess, and a remarkable lack of spontaneity and initiative in such work. These defects in our educational system ought not to be, and it will try the mettle of our educators to remedy them.

THE TREASURY DEPARTMENT VS. FREE IMPORTATION OF SCIENTIFIC APPARATUS BY SCHOOLS.

BY H. N. CHUTE.

It is not often that one looks for the humorous in a government circular and is rewarded. But this is an age of surprises, and perhaps not one of the least of these surprises is to find a government department with a supposedly sane man at its head perpetrating such a medley of contradictions and ab-

surdities as characterize Treasury Department Circular No. 87. This circular is ostensibly issued for the guidance of collectors of customs, and claims to be a compilation of readings of the Treasury Department and of the courts in matters relating to the free importation of apparatus by schools. Article 638 of the Act of July 24, 1897, states that philosophical and scientific apparatus, utensils, instruments and preparations, including bottles and boxes containing the same specially imported in good faith for the use and by order of any society or institution incorporated or established solely for religious, philosophical, educational, scientific or literary purposes, or for the encouragement of the fine arts, or for the use or by order of any college, academy, school or seminary of learning in the United States, or any state or public library, and not for sale, subject to such regulations as the Secretary of the Treasury shall prescribe, are exempt from duty.

The real richness of the circular is found in the interpretation that the Treasury Department puts upon what it terms "philosophical and scientific apparatus," as shown by the following examples culled from a long and varied list. "A scale indicating $\frac{1}{20}$ milligramme, and a maximum weight of 100 grains" (about 6 grammes), and "an analytical balance sensible to the seventeen-millionth of an ounce" (about 1-2 milligramme) are declared to be scientific instruments within the meaning of the act; on the other hand, a balance indicating 1-4 milligramme and a maximum load of 100 grammes was declared *not to be a scientific instrument* within the meaning of the act when a prominent high school recently tried to pass one through the New York Custom House. This balance, evidently, did not exactly meet the specifications of a scientific instrument as prepared by the department and so the appraiser accordingly levied a duty of 45 per cent on the same. Again, "aneroid barometers, used for measuring pressure and weight of the atmosphere," are declared to be entitled to duty exemption (cir. p. 5), but "aneroids" are not (cir. p. 6). "Laboratory thermometers, unmounted" (whatever that means) are scientific instruments (cir. p. 5), but "chemical thermometers" are not (cir. p. 6). "A Siemen's wattmeter" is exempt (cir. p. 5),

but a "voltmeter and an ammeter" are not (cir. p. 6). "Barometers" are classed as scientific instruments (cir. p. 5), but "pocket barometers" are not entitled to this distinction (cir. p. 6); the circular does not fix the size of the pocket governing this classification, but leaves it to the judgment (?) of the appraiser. "Objectives" need not pay duty, but "rectilinear lenses" must (cir. p. 6); neither can common lenses of any kind be imported duty free for school use. They are not scientific instruments, according to the Treasury Department. Spy glasses are declared to be strictly scientific, including even the "99 cents for 30 days only" quality; the opera glass, however, must pay duty, unless it is large enough to aspire to the rank of marine glass, when it becomes exempt. Here, again, the determination of class is left to the imagination of the appraiser. Geissler tubes are permitted to enjoy free entry, but the influence machine so largely used to light them and give them value is held up and must pay tribute to Cæsar. "Compound microscopes, if used for examining objects invisible to the naked eye," are classed as scientific, but a microscope that is small, cheap, or such as would be used in examining objects not strictly invisible to the naked eye, as many of the details of plant structure, is not a scientific instrument. Absolute alcohol can be imported duty free, but ether and many other compounds equally serviceable in a laboratory are declared dutiable. The law distinctly says that the boxes containing apparatus are entitled to duty exemption, yet the department has ruled that the case of the compound microscope is not exempt and duty shall be collected (cir. p. 7).

It is by such absurd rulings (and many more could be cited) that the Treasury Department is defeating the clear purpose of the Act and rendering less efficient the scientific instruction in our schools. What is a scientific instrument? This question has been answered by the United States Supreme Court in the Oelschlayer case as follows: "Only such instruments can be admitted to free duty as philosophical instruments as are used for the purpose of making observations and discoveries in nature and developing and exhibiting natural forces and the condition under which they can be called into activity." This definition is cer-

tainly broad enough, and gives any school the right to import any piece of apparatus, no matter how simple or how complex, cheap or expensive, provided it is to be used in making scientific observations or exhibiting the action of natural forces. It would seem that the Treasury Department has clearly no right to interpret the law as indicated by the circular in question and by their actions as well. The science teachers of this country should vigorously protest against such interpretation and bring all possible pressure to bear through the press and Congress to the end that the law may be rationally administered and that the advancement of scientific instruction may not be handicapped by the Chinese wall of exclusion recently erected at the Custom House.

WHAT IS AN INFECTIOUS DISEASE?

BY W. H. MANWARING,

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For several years I have been trying to find a simple method of demonstrating the nature of infection to secondary and grammar-school pupils. It is desirable that there be a widespread understanding of the nature of contagious diseases, in order that sanitary and hygienic actions of medical boards and boards of health may have a meaning in the mind of the public at large. I take it that the creating of this understanding is one of the most important duties of the public schools.

At first, I tried various devices, all borrowed more or less directly from the bacteriological or pathological laboratories, but with unsatisfactory results. The inoculation of a mouse with *bacillus anthracis* and the demonstration, after death, of the organism in blood of the animal by cover-slip and staining methods, did not convey to the minds of the pupils the vivid conceptions I wished. The red-and-blue pictures seen under the compound microscope had little meaning to most of them. The examination of diphtheritic membrane and of consumptive sputum were open

to the same objections; special staining methods had to be used, and that and the compound microscope forced the thing off into a land of mystery and imagination.

What I wanted was a device to bring the facts before them in a vivid and picturesque manner, without staining or culture methods or any of those processes that to the scientist are so simple, but which are so enigmatic to the untrained pupil.

One year, I tried introducing cyclops into a jar swarming with vorticellae. Before many days, some of the cyclops were covered with a squirming, jerking mass of vorticellae, easily seen by a simple lens. By a stretch of the imagination, the mass might be likened to an infection. But the device was unsatisfactory; there was not elasticity enough in it; it did not readily lend itself to the development of the subject.

I have, however, found a device that fulfills, to a quite satisfactory degree, most of the requirements. The material is abundant, every boy and girl can make his observations for himself, it lends itself readily to questions as to methods of prevention, isolation, sterilization and the like, and requires nothing in the line of media, stains or compound microscopes.

In the fall of the year, every boy and girl has seen, lying about or hanging to the ceiling or window pane, the swollen bodies of flies, dead from the fly fungus. The white dust-like spores, the bloated body, the alternate white and black bands of the abdomen, have been noticed by most of them. Then is the time I give my lesson on "The Dead Fly." A simple magnifying glass shows the fungus that killed the insect and the spores about it, and questions like: "How might the fungus have gotten on the fly in the first place?", "If you wanted to kill off all the flies in the room with the fungus, how would you go to work to do it?", "If you found a dead fly and wished to prevent the other flies from getting the disease, what would you do?" and the like, bring out all the essential facts of contagion and disinfection. When this is done, the step to the conception of bacteria, infection and prophylactic measures is simple and is taken by the pupils almost instinctively and with no forcing on my part.

I commend this device to all live teachers of elementary

physiology and hygiene, as I believe it to be the best one for the purpose now before the teaching profession.*

INTRODUCTORY METEOROLOGICAL EXPERIMENTS.

WM. H. SNYDER.

There are few schools at the present day which do not at some point in their course consider the elementary principles of meterology. Very often this work is undertaken without any previous knowledge of physics or with an indistinct remembrance of some experiments and discussions which took place in the dim past. It is therefore almost always necessary to consider the subject *de novo* and develop all the necessary conceptions. If meteorology is ever to be understood, there are a few fundamental principles which must be firmly grasped and upon which as a basis the rest of the subject must be built. I have endeavored to lay this foundation by means of the following simple experiments. These experiments cover about all the considerations necessary for elementary work and can be understood by pupils without previous scientific training.

I. Air Has Weight.—Take a large bottle and weigh it full of air and then weigh again with as much of the air exhausted as possible. The difference of the two weights, which will be appreciable on a pair of ordinary laboratory scales, will be the weight of the air removed. The volume of this removed air can be found by opening the mouth of the exhausted bottle under water and sinking the bottle as the water runs in, thus keeping the level of the water outside and inside the bottle the same. The weight of the water in grams which flows in is approximately the volume of the air removed in cubic centimeters.

II. Air Exerts Pressure.—Take a tube about eighty centimeters long, open at both ends, and over one end slip a short piece of tightly fitting rubber tubing which can be completely closed by a pinch-cock. Having closed the rubber tube, as nearly as possible at the end of the glass tube, fill the long tube with mercury and invert in a cup of mercury. If the connections are tight an ordinary mercurial barometer column will be formed, showing that some force must hold the mercury up. To the average boy or girl, however, pressure means an active

*Those interested in the fly fungus will find a short description of it in the POPULAR SCIENCE NEWS for December, 1901, and in the Literary DIGEST for Dec. 28, 1901.

force. To show that the pressure here is capable of producing motion connect the open end of the rubber tube with a glass tube about 50 cm. long, placing the free end of this in a dish of colored water. Now open the pinch-cock and the colored water will be forced up into the mercury column tube. If a little of the spectacular is necessary to revive the comatose brain cells take a thin glass flask and boil a little water in it till the flask is entirely filled with steam, then, having taken it away from the heat, quickly cork it. Place the flask upon the table and allow to cool. The steam will condense and if the flask is thin enough the air pressure will crush it in. This shows strikingly the activity of air pressure. The Magdeburg hemispheres also show well the fact that air exerts pressure.

III. Pressure Decreases with Altitude.—To show this, an aneroid or mercury barometer can be carried from the bottom to the top of a building and the readings carefully made at each place. The difference must be due to the increase of altitude.

IV. Air Expands When Heated and is Compressed When Cooled.—Bend a glass tube into an S-form and fill the U-arm about half full of mercury. Place one end of the tube through a tightly-fitting cork in a flask. Heat the flask gently and the mercury will be forced up one side of the U-tube, showing an increase in the volume of the air. Place the flask in cold water and the mercury will rise in the other arm, showing a decrease in the volume of the air.

V. Air is Compressed under Pressure.—This is best shown by the use of the Mariotte's tube.

VI. Warm Air is Lighter than Cold Air.—Take two open flasks of nearly like weight and capacity and balance, in as nearly a vertical position as possible, at the ends of a beam-balance. Bring the flame of a Bunsen burner onto the upper side of the bulb of one of the flasks so that the hot air currents that are generated will have no upward component on the flask. The heated flask will rise, showing that the heated air in the flask has less weight than the cold air.

VII. Cold Air Pushes Up Hot Air and Takes Its Place.—Take a tight chalk-box and cut a hole near each end of one side of the box. Place a lighted candle above one of the holes and tightly seal lamp chimneys around each hole. The air will now rise through the chimney in which the candle is and sink through the other. This can best be shown by holding a piece of lighted paper above the cold air chimney. If the paper has been soaked in a concentrated solution of saltpeter and then dried it will give out much smoke when burning. If a pane of glass is put in one of the vertical sides of the box the horizontal air currents can be seen passing through the box.

VIII. Air is Cooled by Adiabatic Expansion.—Take the bottle used in the first experiment and pass through the cork a chemical thermometer

and a short open glass tube. Have the lower end of the glass tube which is close to the bulb of the thermometer, bent away from it so that the air, when exhausted or allowed to enter through the tube, will not impinge upon the thermometer. Now quickly exhaust the air from the bottle, noting the action of the thermometer. It will be found that the thermometer falls when the air is exhausted and returns to its original position when the air is allowed to re-enter the bottle. This movement of the thermometer is not large but easily appreciable.

IX. Air Holds Moisture.—Take a thin nickel cup or glass beaker which has been wiped perfectly dry on the outside and put into it cold water. Soon a mist will gather on the outside of the cup. This moisture could only have come from the air which surrounds the cup. The cup itself is perfectly impervious.

X. Cold Air Holds Less Moisture Than Warm Air.—Take a liter flask and put into it just sufficient water to make a thin film on the inside of the flask when shaken around. Now warm the flask gently, never bringing its temperature near to the boiling point, until the film of water disappears from the inside and the flask appears to be perfectly dry. Having corked the flask, allow it to cool. The mist will reappear on the flask. The air, when warm, was capable of holding as invisible vapor the water which was placed in the flask.

XI. Water Evaporates at All Times.—Carefully weigh a dish of water and place it in any convenient place where there is a free access of air. After some hours weigh again. The change in weight is due to the evaporation of the water. This experiment should be tried under various conditions.

XII. Ice Evaporates Without Melting.—During a cold spell in the winter, when the thermometer remains considerably below the freezing point, carefully weigh a dish containing a number of fairly large pieces of ice. Allow the dish with the ice to remain in an exposed position, protected from the sun and all heat for a day or so, and then weigh again. The ice will be found to have lost weight, although the temperature has been constantly below the freezing point.

XIII. Moving Air Turns to the Right in the Northern Hemisphere.—This can be shown by moving a piece of chalk, kept in the same vertical plane, from the pole to the equator of a globe revolving from west to east or by moving a body impelled by the equatorial velocity from the equator towards the pole. It is somewhat difficult to illustrate the latter condition, but it can be roughly shown by keeping the hand holding the chalk always opposite a certain marked point on the equator and moving the chalk vertically.

XIV. Formation of Clouds.—On a day when the room is rather cool, heat a small amount of water in a large flask to a temperature of about 80 degrees C. Through a cork in the mouth of the flask extend

two glass tubes bent to an angle of about sixty degrees. One of these tubes should reach nearly to the top of the water in the flask and the other merely through the cork. Now blow from a bellows or from the lungs through the shorter tube. Moist air will be driven out through the longer tube and coming in contact with the cooler air of the room the temperature of the mixed air will not be sufficiently high to keep the contained moisture in the form of invisible vapor and a small cloud will be formed. This is not a condensation of steam, for the flask was kept far below the point at which steam is formed, but is a mixture of moist warm air and a colder air. This is one of the most common methods of cloud formation.

XV. Composition of the Air.—In a large, tightly corked bottle, burn by means of a deflagrating spoon a small piece of phosphorus. When the phosphorus has ceased to burn and the fumes have settled, open the mouth of the bottle under water. Water rises in the bottle to take the place of something which was removed by the burning of the phosphorus, but there still remains a gas present with which the phosphorus did not combine. This residue is colorless and transparent like the air, but unlike it neither phosphorus nor a match will burn in it. It cannot be air. Now replace the water which has entered the bottle with oxygen made in the ordinary laboratory way and see if phosphorus will burn in this mixture of the unburnable gas and oxygen in the same way that it did in air. It will be found to do so. It is fairly evident then that one of the constituents of air is oxygen and that another is the unburnable gas which may be called nitrogen. To show whether there is any other constituent, draw, by means of suction, oxygen and nitrogen through lime water and afterwards draw air through it. Neither the oxygen or the nitrogen affect the lime water while the air makes it milky. There must be some other invisible constituent in the air besides nitrogen and oxygen which may be called carbon dioxide.

PRESSURE OF LIQUIDS.

BY H. D. MINCHIN.

Instructor in Physics, Detroit Central High School.

The problem of determining the pressure of liquids due to their depth has been given much attention, but the methods hitherto adopted have, in general, been quite unsatisfactory. My experiments have been directed towards determining the amount of pressure in terms of our standard weights. The method employed is that of using a tube with a rubber diaphragm stretched

across one end. This is submerged in water at different depths and the pressure recorded for each position.

The apparatus (Fig. 1) consists of a glass cylinder for water, a thistle-tube, and an indicator. Across the bowl of the thistle-tube is fastened a rubber diaphragm, and into the tube passes a plunger with a flat disk of wood on its lower end that rests upon the diaphragm. To the upper end of the plunger is fitted a pan for the weights. To the outside of the glass cylinder is attached a scale for reading the depth of the water. A thin board is clamped across the top of the cylinder; this serves as a support

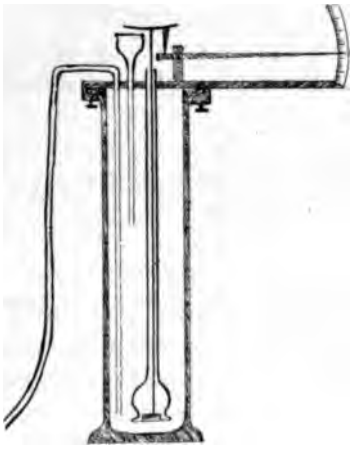


Fig. 1

for the thistle-tube, the indicator and scale, and any other parts which may be added for convenience, such as a thistle-tube for filling the cylinder with water, and a siphon for removing water when desired.

When readings are to be made the apparatus is set up, adjusted and the zero of the indicator marked. To eliminate the error due to the difference in tension of the diaphragm, the indicator is brought to the zero mark at each reading and the weight required to so adjust it is recorded.

Water is added to any depth and weights are then placed in the pan sufficient to bring the indicator to the zero mark. Then

more water is added and the adjustment is again made, and so on.

The following results show what the apparatus can do:

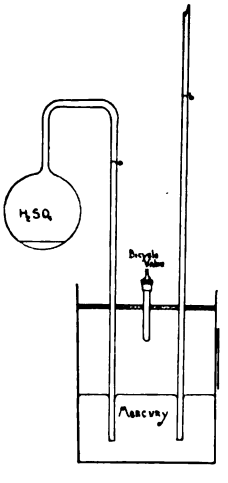
	Depth of water in cylinder.	Depth of gauge in water.	Weight added to adjust.	Pressure per cm. Depth.	Depth per 1 g. pressure.
	cm.	cm.	gram.	gram.	cm.
1	11.00	0.00	0.00	0.00	0.00
2	15.50	4.50	48.00	10.66	0.093
3	19.50	8.50	90.00	10.59	0.094
4	25.00	14.00	148.00	10.57	0.094
5	29.50	18.50	196.00	10.59	0.094
6	36.50	25.50	268.00	10.51	0.095
7	44.00	33.00	350.00	10.60	0.094

The fourth column, by the constancy of the results, indicates the relation between the depth and the pressure.

THE COEFFICIENT OF EXPANSION OF AIR AT CONSTANT VOLUME.

BY F. A. OSBORN.

Professor of Physics, Olivet College, Mich.



The accompanying figure will give all necessary details concerning the construction of the apparatus, which is simply the Boyles' Law Apparatus of Mr. N. H. Williams, of the Indianapolis High School, slightly changed in form.

The bulb has a capacity of about 250 cc. capacity. It is immersed in ice-water for 10 or 15 minutes, and then the mercury, by means of a bicycle pump is forced up to the mark *o* on the capillary stem. The readings at *o* and *b* are taken by means of a mirror-scale placed back of the tubes. The temperature should also be read at this time.

The bulb is then put into water at a temperature not much

above 30° C., and the mercury is forced up to the mark *o*. After 15 minutes the readings at *o* and *b* are taken, as well as the temperature of the water.

If we let P, P_1 and P_o represent the pressures at the low temperature t, the high temperature t_1, and at zero respectively and a the coefficient of expansion, then $P = P_o(1+at)$ and $P_1 = P_o(1+at_1)$.

$$\text{Hence } a = \frac{P_1 - P}{Pt_1 - Pt}.$$

The following results were obtained successively with the apparatus: 0.00356, 0.00357, 0.00368, 0.00366, 0.00376, 0.00365, 0.00361; mean, 0.00364, which, when corrected for expansion of glass, becomes 0.003666.

SPECIFICATIONS FOR A CHEAP AND SERVICEABLE SPECIFIC GRAVITY BALANCE.*

BY W. E. BOWERS.

Instructor in Physics, Tolt (Wash.) High School.

Section through base and standard. (*Fig.* I.)

Base (B), cast iron, 5¼" in diameter, drilled at center (C), for reception of standard; standard (S) of 5-8" steel bicycle tubing, driven into base. Both enameled.

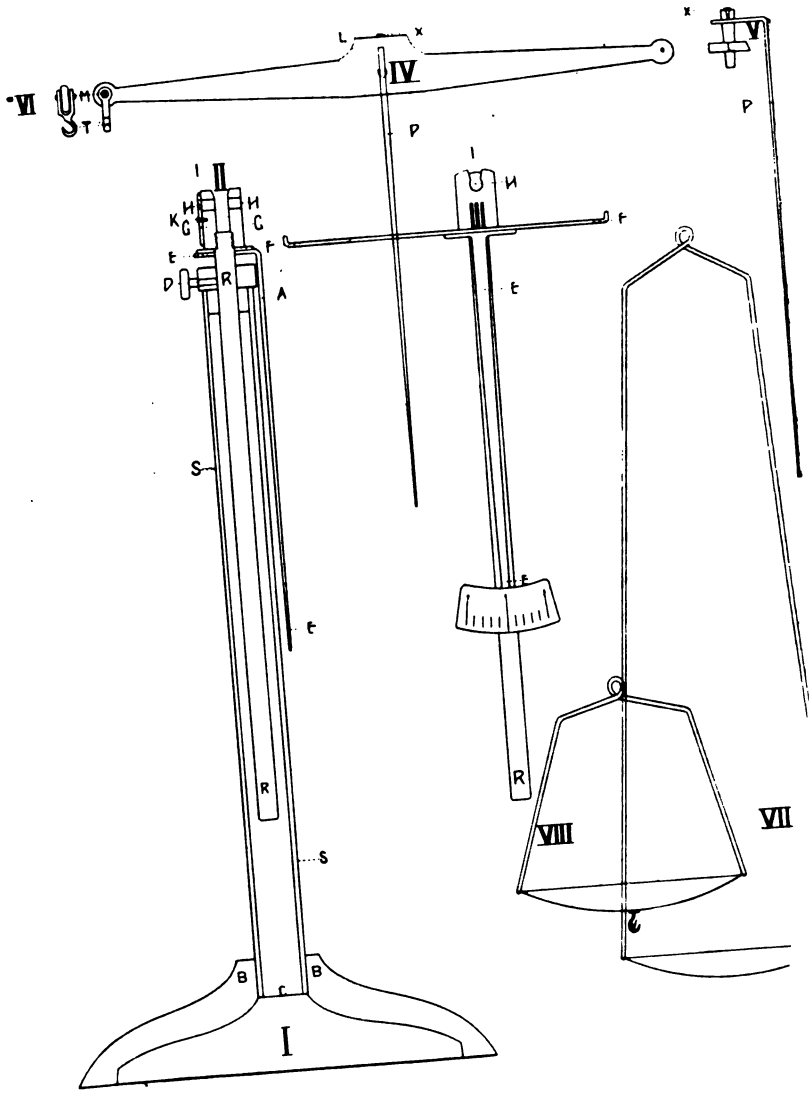
Thimble (A) of soft steel, turned and polished, with set screw (D), soldered into tube.

Side View of bearing and device for raising. (Fig. II.)

Front View of Same. (Fig. III.)

Rod (R) of 5-16" cold drawn steel, turned down to 3-16" at top, and provided with threads to move smoothly in (A). Scale (E) of sheet steel, 1-20" thick. Beam arrester (F), 1-20" steel, 6" long and ⅜" to ⅝" wide. Block (G) for main bearing, cut from soft steel, shaped with milling wheel, drill and file, and hardened; 1"x1-2x1-2", proportions as in figure. Space for pivot, (H). Plate (I) to prevent friction of beam (end of pivot rests against plate), held by screw (K).

*See this Journal, Vol. I., p. 156.


VI
IV
V
VIII
VII
I
S
R
B
P

Front View of Beam. (Fig. IV.).

Section through Middle of Beam, Pivot, etc. (Fig. V.).

End View of Beam with Hook. (Fig. VI.)

Beam forged from soft steel and hardened; total length, $8\frac{1}{8}$"; greatest width, 13-16"; thickness at middle at upper edge, 3-16", at lower edge, $\frac{1}{8}$", and at the ends, $\frac{1}{8}$". Pivot (L), hardened steel, may be filed or ground sharp if it becomes dull. Pivots (M) located $4\frac{3}{4}$" from (L), measuring from knife edge to knife edge. Pointer (P) of steel wire, held by a set screw (X). Hook (T) for pan.

Right Hand Pan (Fig. VII.) of spun brass, bronzed, suspended on spring brass wire. Diameter, $3\frac{1}{8}$"; depth, $\frac{1}{2}$"; total height, 11 11-16".

Left Hand Pan (Fig. VIII.), exactly like the right hand one, except that it has a hook (V), and the total height is only $4\frac{1}{8}$".

These scales are suitable for *all* work of the laboratory where great accuracy is not required. Their maximum load is about a kilogram, although such a load would, however, somewhat lessen their sensitiveness. When new they are sensitive to a centigram. A set of six, as described above, were made in Willmar, Minn., for $18.00.

The following remarks will suggest a few of the difficulties and may perhaps be of service in avoiding them.

The block for the main bearing must be sawn and drilled perfectly true, and fit true upon the sliding rod, so that the beam will not be inclined to slide to either side.

If there is difficulty in getting the knife edges (M) at *exactly* equal distances from (L), the beam may be heated and stretched by judicious hammering, also twisted, if needs be, to bring the knife edges into exact line.

Bending the beam so as to bring the ends lower makes the balance sensitive to a smaller weight, and also more liable to swing suddenly in the annoying way that some balances have. In these balances a line drawn between the knife edges (M) and (M) passes 1-32" below the edge of (L); they are quite satisfactory in that respect.

The beam should be forged, drilled, filed until nearly balanced,

"trued up" and fitted with the pivots, which should be square bars filed to shape; the balances are then polished, balanced perfectly, fitted with the hooks and again balanced. This balancing must be done by (*a*) having the knife edges at exactly equal distances, and (*b*) by filing and polishing. Next the pans, already bronzed and made of nearly equal weight by adding solder to the shorter one, may be attached and the scales balanced again by putting on or taking off solder.

On putting away these balances, the bright parts should be wiped with a cloth moistened in sperm oil. If the physical laboratory is damp or closely connected with the chemical laboratory, it would be well to have all parts enameled, except the knife edges and bearings which can be kept oiled.

Sets of weights should be purchased of an apparatus dealer; no local workman can compete in workmanship and accuracy with the factories where the weights are stamped out or molded, without having to charge too high prices.

A SIMPLE SPECIFIC GRAVITY BOTTLE FOR GASES.

BY ARTHUR W. GRAY,

Instructor in Physics, Merced County (Cal.) High School.

A worn out incandescent electric lamp bulb makes an excellent specific gravity bottle for use with gases. The bulb, together with about half a cubic centimeter of soft wax, is counterpoised on a balance which is reliable to a centigram. Air is then admitted by cautiously filing through the side of the tip by which the lamp was sealed when exhausted at the factory. The mass of this air is now determined by restoring the equilibrium of the balance with standard masses, care being taken to replace on the balance pan any bits of glass broken off.

The air is then replaced by any desired gas, which is admitted through a small glass delivery tube inserted through the hole made by the removal of the tip. After the gas has flowed long enough to

displace all the air in the bulb, the delivery tube is removed, the opening sealed with the soft wax, and the whole reweighed to determine the mass of gas that fills the bulb.

When this process has been repeated with as many gases as desired, a small funnel is inserted in the opening and the bulb filled with water, whose mass is determined to within a gram by weighing on a coarse balance. The bulb may be emptied of water by inserting through the opening a glass tube to admit air.

In order to test the reliability of this method, I had each one of my sixteen pupils in physics determine independently the specific gravity of air referred to water, of coal gas referred to water, and of coal gas referred to air. Each of the 32 c. p. incandescent lamps used held a little more than three decigrams of air, so, with a balance not reliable beyond a centigram, no greater accuracy than three per cent could be expected. The mean of the sixteen values reported for the specific gravity of air was 0.00116. The results differing most widely from this were 0.00108 and 0.00125, while the mean variation from the mean was 0.000039, or 3.4 per cent of the mean. In judging from these figures, it should be borne in mind that the pupils were given no more assistance than absolutely necessary to make sure that they understood the method, and that in every case the first result reported to me was accepted, because it was desired to give the method as rigid a test as possible under the circumstances. If the two highest and the two lowest results be rejected, the mean remains the same as before, but the mean variation from this reduces to 2.3 per cent. The separate determinations were made on different days with the barometer ranging from 75.7 cm. to 76.6, and the temperature from 18.5° C. to 20.8° C. I neglected to have a wet-bulb thermometer read also, but I have good reason to suppose that the water vapor present in the atmosphere of the room was nearly saturated. The results obtained by the class were uniformly a little lower than that calculated for air under the above conditions of temperature, pressure and aqueous vapor. Possibly this discrepancy was due mainly to the presence of a small amount of air or other gas in the worn-out lamp.

With coal gas the agreement of results was not so good, the

mean variation from the mean being about 6.5 per cent. This seems due mainly to two causes, first, a 32 c. p. lamp holds only about two decigrams of coal gas, so that no greater accuracy than 5 per cent could be expected with a balance unreliable beyond a centigram; second, it is difficult to make sure that all the air has been driven out by the gas. Carbon dioxide or some other heavy gas ought to give better agreement among the results of the various pupils, but coal gas has the advantage of being convenient.

To secure a fair degree of accuracy the lamps used should be of thirty-two candle power or larger. A fresh bulb is, of course, necessary for each pupil, but these may be obtained for the asking from the local electric light company. Bulbs whose tips have been removed make, however, fairly good specific gravity bottles for use in the ordinary way with liquids.

THE GAMMARUS AS A SUPPLEMENTARY TYPE.

BY EDGAR A. BEDFORD,
Instructor in Biology, Lake View High School, Chicago.

The amphipod, *Gammarus,* affords an excellent form with which to supplement the laboratory work on the crayfish. It not only offers many good points for study, but it is also easy to obtain and easy to keep. A bunch of *Anacharis* brought in from a collecting trip is usually certain to furnish a good supply of material which may be kept almost indefinitely by being placed in aquaria jars. The material used here a short time ago was collected nearly a year previously. The decomposition of a portion of the *Anacharis* seems to cause the animals to thrive even better than before. I observed in September that they had been breeding during the summer, there being present large numbers of the young.

The following are some of the points to which the attention of the student may be directed:

1. Number of free somites present as compared with the number in the crayfish, and the possible bearing of this upon the position of the *Gammarus* in a classification of the crustaceans.

2. Differentiation of the locomotor appendages into three groups for walking, swimming and jumping or kicking.

3. The simple structure of the gills, being separate, finger-like processes attached to the coxal joints of the thoracic legs.

4. The eyes, the facets of which are not closely approximated, thus giving the eye the appearance of being a collection of ocelli.

5. Blood currents, which can be observed in this animal most excellently. The beating of the elongated heart and the currents of blood entering through the valvular openings in the side of the heart may be plainly seen. In the appendages good examples may be observed of currents passing towards the periphery, and of returning currents.

It may be of advantage to have pupils make tables similar to the following:

1. Jointed legs.		
2. White blood.		Characteristics of ARTHROPODA
3. Made on somite plan.		
4. Covered with chitinous shell.		
5. Breathe by gills.		Characteristics of CRUSTACEA
6. Two pairs of antennæ.		
7. Legs on thorax and abdomen.		Characteristics of MALACOSTRACA
8. Six somites in abdomen.		

A table of differences may also be made, arranging the characteristics of the two animals in parallel columns.

Since the work is done entirely with the living animal, its movements may be so rapid as to make observation difficult. These may be slowed down, however, by the use of chloretone in 0.5 per cent solution. To a small quantity of water with the *Gammarus* in a watch glass add two or three drops of the chloretone solution. If this is sufficient, the animals will begin to move more slowly in a minute or so. If they become too stupefied, add fresh water. By proper use of chloretone and water, the animals may be kept in the desired condition for some time, and they will quickly revive when placed in fresh water.

THE CAMERA IN ZOOLOGY.

BY W. H. MAC CRACKEN.

Almost every one uses a camera more or less, but I think it safe to assert that very few people can be said to actually take photographs, and still fewer are those who have really done any experimentation in photography, with a definite purpose. Up to the present time there has been quite too much of the button-pressing work, and the taking of photographs has been more a matter of recreation than of practical utility.

There are several reasons for this, as I shall try to show, but just now I wish to emphasize those points which should make the camera an indispensable adjunct to any biological laboratory.

In all scientific work it is necessary that we aid and support defective memory in some way or other, a fact which has led to the use, perhaps ultimately to the abuse, of the note-book, and which has brought laboratory sketching so much into vogue. In notes, and still more in sketches, we have to take into account the element of personality. Especially is this true when the subject studied is alive and moving, as most zoölogical matter is or should be. No two people see alike, and if two students make sketches of a somewhat complex motile organism, it amounts to a certainty that they will turn out contradictory pictures.

The camera, I need not say, is entirely impersonal. Once it is focused and adjusted properly, it makes no difference whether you or I make the exposure. In the matter of detail, our results will be precisely the same. Moreover, no one ever *drew* a picture of a moving animal for the simple reason that even a snail moves faster than it can be drawn. So that a sketch is at best a series of efforts of memory, and need not when complete resemble the animal in question, and unless made by a highly trained student is of very doubtful accuracy. Setting against this the fact that the entire picture with the exactness of detail in light and shade is possible

with the camera in 1-100 of a second or less, the advantage of the instrument appears at once.

It may be urged that the student in drawing comes to observe his subject more closely than he otherwise would.

For my part, I don't want a student of mine to observe an animal for the sake of being able to draw it in his note-book. I can scarcely imagine a more unscientific procedure. Besides, I am by no means sure that in a case where an organism moves slowly enough to admit of prolonged observation, or is stationary, a student will not observe it quite as closely in the work of accurate focusing, etc., as he would while hurriedly engaged in making a rough drawing.

For the working scientist there can scarcely be said to be any choice. The camera, properly designed and used, will win the day *every time*. It is worthy of note that in court the evidence of the photograph is accepted when the drawing is refused.

The camera is being used more and more as we appreciate the importance of studying plants and animals in relation to their environment.

Along this line, the botanists are, for obvious reasons, ahead. And many recent works owe their greatest merit to their photographic illustrations.

To my mind a great point in favor of the camera as a zoölogical instrument lies in the use that can be made of it in recording the metamorphoses so common in the life histories of many animals.

I have in mind a series of photographs which I took of *Attacus Cecropia*. These begin with the cocoon, and end with the moth with wings completely expanded. As an experiment, I mounted these pictures on a roller so that they could be presented to view in rapid succession, kinetoscope fashion, and though there were only a dozen, I was still able to demonstrate the process very nicely, and the great moth would apparently work its way out and expand (in rather a jerky fashion, to be sure), and in a few seconds instead of several hours.

In regard to the camera, there is no such thing as an "all-

round" instrument. You may be certain, if you haven't used one, that the ordinary camera sold by opticians, druggists, newsdealers and hardware men, and offered as a premium for selling soap to your neighbors, will never be of the slightest scientific use, even though it may take pretty little pictures.

Another misstatement which we often read is that it is all in the lens. This isn't so. The mechanism is extremely important, and while this or that man may boast of having taken good pictures with a lens screwed into a cigar box, I can't advise anyone to follow his plan.

The laboratory camera may be used to take landscapes and portraits, but is not to be recommended for that purpose. It must be a long bellows instrument in order to admit of varying adjustment, and should have several lenses of various focal lengths. To catch the motion of a bird's wing, it must work in 1-500 of a second, and then will fail to give a clear image in the case of a humming bird. There is no time given for micrometric focusing, Some companies are making a convertible lens that, by shifting of parts, can be made to answer all purposes.

One combination of my lens gives a focal length of 22 inches, necessitating a bellows length of nearly 3 feet, and I have often wished that I had a longer one still, for only with a lens of great focal length can an ordinary object be shown well in focus and without distortion.

Another important thing is to get the biggest, best lens that your pocket-book will allow, for those of long focus are slow, and a lens that will cut clearly to the edge of the plate with a sufficiently large aperture for instantaneous work is costly.

The camera must be constructed to work in any position. In the laboratory of the University of Buffalo, I have often found it convenient to point the lens straight downward, and again toward the ceiling. So much for the laboratory camera.

To do satisfactory work on wild animals and birds is still harder, on account of their great freedom and rapidity of motion. Very recently I contrived a piece of experimental apparatus, by means of which I have had a little success.

I took two lenses, each of 20 inch focal length, and set them so that I had a sort of double-barreled camera. One lens focused on a two-inch square piece of ground glass, and the other on the surface of a film, beside it. The two cameras being parallel, of course the picture on the ground glass was exactly like the image on the film, and by watching the glass I could tell just what sort of a picture I would get, and just when the subject was in focus. So the instant of springing the shutter was determined to a nicety.

At present scientific photography is in the act of being born. Many hard problems are as yet unsolved, and this is largely for lack of time and money for necessary research. Still work is being done, and perhaps even you and I may yet be able to put our nickel in the slot and watch the caterpillar turning to a chrysalis, the mother bird feeding her young, or a battle between rival stags, instead of a slugging match between pugilists.

A CHEAP AND EFFICIENT OXYHYDROGEN ELECTROLYTIC APPARATUS.

BY C. E. LINEBARGER.

At the prevailing price of platinum anything but a quite small electrolytic apparatus, with dilute sulphuric acid as electrolyte, is beyond the reach of most high-school laboratories. But by using sodium hydroxide as electrolyte and iron or nickel electrodes an oxyhydrogen apparatus can be readily and very cheaply made of almost any size, which will compare very favorably with those furnished by dealers. A form which I have used now for three years past is the following: A wide-mouthed bottle of 500 to 1,000 cc. capacity is fitted with a one-hole rubber stopper. From ordinary sheet iron, rectangular pieces are cut of such a size that they can just be pushed into the bottle. Stout iron wires are attached to one end of these electrodes by bending the sheet metal over on the wire and hammering it down well. Two holes are pierced with an awl through the stopper, through which the wires are thrust. An L-tube is inserted in the stopper. The bottle is

nearly filled with a solution of sodium hydroxide of about 10 per cent strength. It is very essential that this hydroxide be free from chlorin, else the iron would be attacked. Commercial sodium hydroxide, even that purified by alcohol, almost always contains enough sodium chloride as to render it worthless for the purpose under discussion. The solution may, however, be prepared by dissolving clean bits of sodium in water or dissolving sodium peroxide in water. (It is my practice to have the residues from the preparation of oxygen by action of sodium peroxide in water placed in a bottle, the sodium hydroxide thus prepared to be used in subsequent experiments.) The electrodes are then placed in the bottle, care being taken that they do not touch, and the stopper inserted tightly. The protruding wires are bent down over the cork, and can be connected with an electric current by means of double connectors. A piece of rubber tubing provided with a delivery tube is slipped over the L-Tube, and the apparatus is complete.

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

EXPERIMENT XXI.

To determine the latitude approximately.

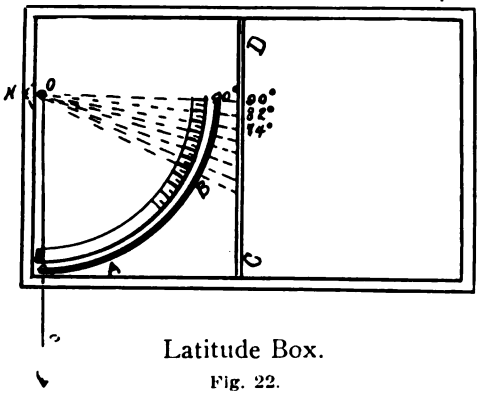
(a) Set a stake vertically on a level surface, and measure the length of the shortest shadow during the day. Also measure the height of the stake. Draw a right angle on paper, and to any convenient scale plot these measured lengths on its sides. Connect the ends of the plotted lengths and measure with a protractor the angle which is adjacent the side representing the length of the shadow. This angle will be the slant of the rays to the horizon. Take the declination of the sun for the date from the *American*

*For the convenience of those who may desire to use these experiments (there are forty-four of them) in their classes, they may be obtained in pamphlet form from "The School Science Press," Ravenswood, Chicago, at 25 cents a copy, and $2.50 a dozen.

Ephemeris, or from *The Old Farmers' Almanac* (Wm. Ware, Boston, price 10c.), add this to the measured slant and subtract the sum from 90°, and the difference will be the latitude.

(b) With the aid of the plumb-line gnomon (Fig. 21), described above (Experiment XX, (a), (2)), the length of the radius of the circle on which the shadow of the bead falls when it is nearest the bob and the height of the bead above the surface of the board may be used as the shadow length and height of stake above.

(c) Perforate the middle of one end of a pasteboard box with a needle-hole, *H,* near the bottom. Graduate into degrees a quadrant described with a point, *O,* on the bottom of the box, as near



Latitude Box.

Fig. 22.

the needle-hole as possible, as a center. A strip, *AB,* of cardboard may be bent around the arc, and pasted or glued to the bottom of the box. Or, a straight strip, *CD,* may be fastened across the box, and the graduations may be transferred to it then, as shown at 90°, 82°, etc., until *C* is reached, when they may be transferred to the lower edge of the box. (This idea is due to Professor Todd, of Amherst College.)

To use the box. Place it in position with its bottom against a vertical north and south wall, or more accurately, within the meridian plane, determined as in the last experiment, so that the plumb-line, *OP,* hangs just above the zero graduation mark. The image of the hole, *H,* cast by the sun at noon may then be seen on

AB or *CD*, and the corresponding reading be made. This gives the zenith distance of the sun directly, and with the almanac declination of the sun for the date, the latitude will be found from—

Zenith distance *minus* the declination, when the sun is south of the equinoctial (from September 22d to March 21st) and zenith distance *plus* the declination when the sun is in north declination (from March 21st to September 22d.)

Experiment XXII.

To construct a crude transit instrument.

(a) The vertical north and south wall of a building, or of two stakes set vertically in a line parallel to such a wall, may be used as a crude transit instrument by placing the eye against the north edge of the wall or north of the north stake, the observer looking southward, and noting the time when a star, or other heavenly body, passes behind the wall, or across the plane of the two stakes.

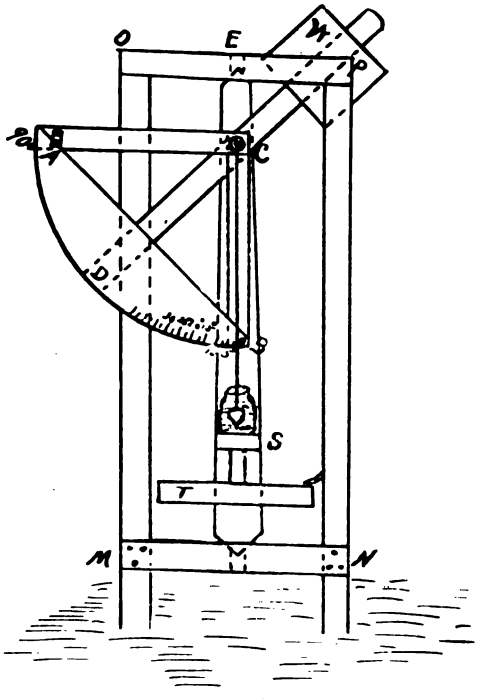
(b) A very good crude transit instrument is obtained by setting four vertical posts, or gas-pipes, in the ground as suggested by the cut of Experiment XX. (a), (1). The posts should be six to eight feet high, the long side of the rectangle inclosed by the feet of the uprights, being north and south. Suspending a continuous plumb-line, carrying a bob at both ends (the bobs may be allowed to swing in vessels of water to avoid the effects of the wind), the vertical portions of the string, or either vertical end segment with the horizontal middle segment will fix the meridian plane after it has once been fixed by star observations as suggested in Experiment XX, and the east and west top cross-pieces have been notched at *A* and *B*. North stars may be observed by placing the eye south of the south vertical end and looking northward, and south stars by standing north of the north end and looking southward.

(c) By the home-made apparatus explained on page 23 of Miss Byrd's *Laboratory Manual in Astronomy* (Ginn & Co.), a book which is highly recommended to all interested in elementary practical astronomy.

Experiment XXIII.

Construct a wooden altazimuth instrument.

With a radius of two feet describe on and cut out of a 7-8-inch board an arc, *ADB*, and graduate it to any desired accuracy. With inch oak stuff frame together a quadrant, as *ACBD* in the cut. Bolt it at C to an upright, *EF*, tapered at either end to fit



Wooden Altazimuth.
Fig. 23.

conical holes, in two pieces, *OP* and *MN*, which are nailed to two posts set firmly in the ground. Leave the bearing loose enough to allow the quadrant to move freely about *C*. The stick, *DC*, may be allowed to extend beyond *C* far enough to carry a weight, *N*, for a counterpoise; otherwise the bearing, *C*, should be adjustable.

(*To be continued.*)

Metrology*

DECADENCE OF THE VULGAR FRACTION.

BY RUFUS P. WILLIAMS.

The small boy who in answer to the question, "What is a vulgar fraction?" indignantly replied, "You mustn't expect me to know about anything vulgar," was ahead of his time. This term exists only in the memory of old inhabitants, having been long ago replaced by *common* fraction. The latter name is even more a misnomer than the former. The uncommon common fraction! It may be that few people, even teachers, are aware of the rapid change, during the last generation, in computing and representing "broken numbers."

The origin of numbers takes us back to the earliest childhood of the race, and one of the most interesting studies of primitive civilization is on the beginnings of notation, when the untutored savage set aside one for every ten fingers he counted. No one can say how old is the decimal system of notation. The Bible gives numbers in multiples of ten; for example, Genesis, 6, 15, in describing the size of the ark. Hindus, Persians, Egyptians, Greeks and Romans employed such a system. Even the tribes of American Indians in their games, played with sticks, bones and shells, kept their count in groups of ten, and students of low races cite scores of similar cases. Counting up from unity and carrying one for every ten was well nigh universal, though there have been other radices, such as 2, 5, 20, etc. But dividing or counting downward from unity was originally an entirely different matter. The first division of the unit must have been into halves, then quarters, etc., for the savage who could not understand a tenth could easily see half of anything. Indeed, the first addition also may have been with two, not ten, as the root.

Greeks, Romans and Hebrews using letters to represent their

*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.)

numbers, made their developments of arithmetic under great disadvantages. The Hindu place system with zero, known to have been used in India as far back as 669 A. D., was probably introduced into Europe in the last part of the 12th or first of the 13th century, and coming by way of Arabia was called the Arabic notation. By virtue of its great superiority it rapidly spread and by the end of the 13th century was known and used by all European scholars for the expression of integral numbers. Vulgar fractions were for a long time the only ones in use, decimals being unknown. As division is more difficult than multiplication, it took 400 years more to invent and apply the decimal point, representing units divided by ten, one hundred, etc., at the right of the point. Stevinus about 1585 was "the first person who advocated and exemplified the use of decimals." Not before the beginning of the 18th century were these fractions generally understood, being at first applied as abstract rather than concrete quantities. But with decimal coinage and the metric system a great change appeared. Everything metric is decimal, and the adoption of this system crystallized decimal fractions and made their use imperative. Division came to be as important as multiplication. The processes being like those with whole numbers—except as to placing the point—scholars were not slow to recognize the advantage over the vulgar fraction of this mode of expression. About 1782 Jefferson recommended decimal coinage. In 1790 Talleyrand and the French Academy advised decimal weights and measures. Gradually this best of all systems has found its way into every land. It has got into the monetary systems of the world in which all civilized nations except three have a more or less perfect decimal coinage. The same is true of weights and measures, but with more exceptions. In countries where the system has had longest concrete application decimals are most common. In those in which the metric system is but partially in use, the old vulgar fraction holds sway, but even there we note a strong tendency to decimalize, which only means the bringing of measurements and computations into harmony with an adopted scale. Once adopt such a scale and sooner or later arithmetical processes are all dominated by it. By a process of *natural rejection* every other system is

pushed to the wall. If a decimal scale is best for addition or multiplication, it is best for subtraction or division; if best for working from right to left, it must be best from left to right; best for whole numbers, best for fractions. It is a good rule that works both ways.

Large common fractions are comparatively useless; they convey little idea, and operations upon them are most tedious. In practical life they are now generally given up. Probably the simpler common fractions, such as half and quarter, may never go wholly out of use, and there is no good reason why they should not continue to be used where necessary; but in proportion as decimals are more used, there is less call for them. The change in the United States within the last few years has been rapid, though all of it has not yet got into the arithmetics or schools. Metric tables and problems are usually relegated to the appendix of the text book, and are rarely seen by pupils, while common fractions are more studied than decimals. Schools must soon adapt their instruction to the new conditions.

Scientific workers the world over use the decimal system whether or not they employ the metric. They use it because it is best. They travel the easiest road while the populace stumbles along some other way. The teacher of physics and chemistry, as of other sciences, requires his students to measure, weigh and compute by the metric system, and problems are worked and answers expressed by the use of decimals almost exclusively.

In the accurate work of machine shops the use of decimal divisions is becoming well-nigh universal, the inch being divided into tenths, hundredths, etc., where the metric system is not employed. In surveying if the foot is used it is almost always the practice to decimalize. The vast amount of time saved by using Gunter's 100-link chain in the last 300 years cannot be estimated. The decimal notation is, with a few exceptions, wholly used in astronomical work to express both time and arc. The day, the hour, the minute and second are subdivided by ten. Even in common life the mind is moving away from vulgar fractions. Instead of saying that an article costs four-fifths more or one-half less than another, we say 80 per cent more or 50 per cent less. A score of years ago nothing was more common in the shops than

goods marked 12½, 16 2-3, 33 1-3 cents. Today the fraction is mostly abolished, 12, 17, 33 cents being substituted.

(*To be concluded.*)

Notes.

PHYSICAL.

When no Galvanometer specially fitted for the deflection of a beam of light is at hand, this crude device will sometimes be found to be serviceable, if it is desired to render the deflection due to the current visible to an audience. Attach to the end of the horizontal needle of a galvanometer a bit of straw extending vertically upward, place the galvanometer in front of the condenser of the lantern and project the straw on the screen. When the needle turns through any considerable angle, the straw is, of course, thrown out of focus, yet this will not be found to be a serious drawback in qualitative work.

G. F. S.

The Motion of the Leaves of an Electroscope is often difficult to render visible to a class. When a projecting lantern is accessible this plan may be followed: Construct an electroscope from a thin-walled flask, being sure to insulate the metal from the glass by paraffine or sealing wax. Place the instrument in front of the condenser of the lantern and focus the leaves on the screen. If the flask is thin, the glass will scarcely interfere with the sharpness of the image. A wire leading from the lecture table to the knob of the instrument completes the outfit. The lecturer can use the end of the wire near him for tests, and the class can see the resulting motions of the leaves on the screen.

G. F. S.

The Handling of Mercury.—A glass tube (quill size) drawn out to a fine jet, can be used to great advantage in handling small quantities of mercury. A supply of mercury can be drawn up pipette-fashion into the tube, and the tube then held horizontally so that the capillary attraction in the tip will prevent the liquid from running out. By inclining the tube somewhat very small amounts can be nicely delivered where wanted, as on the pan of a balance. When larger amounts are to be handled, a round bulb is blown very near the tip. Such a pipette is also very convenient in removing mercury from mercury-sealed stopcocks, etc.

Bottles may be provided with a stopper through which is passed a stout capillary tube bent at an angle of about 45 degrees, and the bottle filled with mercury. By inclining the bottle very small amounts of the mercury may be discharged quite nicely, especially if the capillary be rather fine.

The Radiation of Heat.—An experiment which cannot fail to make pupils think and which may serve as an appropriate introduction to the subject of radiant heat is the following: Hold the palms of the two hands (which must be at the same temperature) about a centimeter apart. A sensation of warmth is felt. The experiment being so simple and readily performed always arouses attention and interest, and it is easy to direct the discussion to other not so apparent cases of heat radiation.

Zeit. f. d. phys. u. chem. Unterricht, XV. 26. A. HOFLER.

Iodo-starch Paste as a Heat Indicator.—As the dark blue compound of starch and iodine becomes colorless at temperatures above about 80 degrees, use may be made of this fact to demonstrate the slight heat conductivity of water, its greater specific gravity when cold than when hot, and convection currents. Several grams of starch are rubbed up with a little cold water into a paste and then boiling water added, and the mixture boiled until it becomes "clear." A crystal or so of iodine is placed in a little water and enough powdered potassium iodide added to cause the iodine to dissolve in a short time. It is then mixed thoroughly with the starch paste. Enough of this iodo-starch paste is added to a long test tube, nearly filled with water, to impart to the latter a dark blue tint. When the *lower* part of the test tube is heated in a Bunsen flame, the *whole* liquid soon becomes colorless. If the entire length of the test tube be now put in cold water, the liquid becomes blue again, commencing at the bottom, and it can be observed that the water near the walls of the tube, which becomes cooled first, flows downwards. When the tube is again heated so as to discharge the color, and its *lower half* placed in cold water, the upper and still hot portion of the liquid remains colorless, while the lower and cooled portion turns blue. If the tube be allowed to cool and then be held in a slanting position with its middle part in a Bunsen flame, the *upper* portions of the liquid lose their color, while the lower remain unchanged.

Zeit. f. d. phys. u. chem. Unterricht, XV, 27. F. SCRIBA.

Book Reviews.

Elementary Experimental Chemistry. By W. F. WATSON, Professor of Chemistry and Biology in Furman University, S. Carolina. 13x19 cm., and 320 pages. A. S. Barnes & Co. 1901. $1.25.

This text book, which the author states "is prepared especially for the vast majority of students who take but one course," contains a considerable number of facts, usually carefully selected, deductions and theories stated in such a form that they can be easily understood and remembered. The non-metals and their commonest compounds occupy most of the book, the metals and their salts receiving scant attention.

A commendable feature is the elimination from the text proper of reference data, some of which are collected in an appendix.

Several topics that demand quantitative treatment, such as the gas laws, will hardly be clear to the beginner without considerable supplementary material in the form of explanations, examples and problems.

There are twenty full-page illustrations of the apparatus and materials used in performing the series of experiments outlined. This is certainly a step in the right direction, but it is to be regretted that the author did not see fit to label the different pieces of apparatus and also indicate their use in order to make the illustrations of some value to the "private learner" who is to use the book. The value of these experiments is diminished by the fact that the results instead of being suggested are stated directly.

Aside from the unique illustrations, the most striking and commendable feature of the book is the straight-forward and clear-cut statement of facts.

John Marshall High School, Chicago. GEORGE W. MASSLICH.

Elementary Zoology. By VERNON L. KELLOGG, M. S., Professor of Entomology, Leland Stanford, Junior University. 13x19x2.7 cm, and 492 pages. Henry Holt & Co., New York. 1901. $1.20.

In this book a number of sound pedagogical ideas have been combined. It has retained the good features of the older authors of standard text books, such as Claus, Huxley, Parker and others. It lays a solid foundation, beginning with the structure of some animal types. While the laboratory directions are kept separate throughout the book, it is one of the most successful in combining these with the text. There are three parts and an appendix.

Part I deals with the structure, function and development of animals, as an introduction to the more formal discussion of animals in systematic sequence in the second part. It might be called the European plan. The types used in the introductory part are the toad, the crayfish, the amoeba, the paramoecium and the hydra. These form the basis for a very wholesome discussion and comparison on the "differences and resemblances between the crayfish and the toad"; "modifications of function and structure to fit the animal to special conditions of life"; "vertebrate and invertebrate"; and after the amoeba and paramoecium, "the single-celled animal body," "protoplasm and the cell."

The cellular structure of the toad is followed by "the many-celled animal body," "differentiation of the cell," including division of labor. A thorough study of the structure of the hydra is used for understanding subsequent discussion on, "The simplest, many-celled animals," cell differentiation, "multiplication and development." This is followed by a special chapter on "Development of the toad" (field and laboratory exercise), and one on "The multiplication, growth and development of many-celled animals."

The second or systematic part is not general descriptive zoology, but is a practical combination of the laboratory and descriptive method. Each group is ushered in by a study of the structure of a type followed by a life-history, habits, other animals of the same kind, and ending in the general classification.

Animal ecology as such is a new departure in elementary text books on zoology. This forms the third part of the book and is carried out in good proportion with the other parts. In our estimation it is largely this part of the earlier book on "Animal Life,"* by President Jordan, and the present author that makes that book such interesting and useful reading for high schools. There are four chapters in this part on, "The Struggle for Existence, Adaptation and Species-forming"; "Social and Communal Life, Commensalism and Parasitism"; "Color and Protective Resemblances"; "The Distribution of Animals."

The three appendices give useful information on "Equipment and Notes of Pupils," "Laboratory Equipment and Methods," and "Rearing of Animals and Making Collections." It also includes the usual list of reference books. It would seem desirable to give some simple directions so that some of the more advanced students or teachers who have not had the "training in microscopical technic," might learn to prepare mounts.

Directions for finding the animals, or procuring and preparing them are given in connection with each subject under "technical notes."

Wherever the author has adopted the plan of giving the names of the parts of figures, he has carried out a commendable recent tendency of some elementary text books. Even older students tire of comparing a lot of arbitrary letters with their explanations in fine print underneath the figures, often not even alphabetically arranged. It is a drawback, especially for the young student, not to have the size of the figure-illustrations given. Students should learn to associate the picture with the actual size of the animal.

The language is generally quite unconventional, yet accurate, and so is well suited for an elementary text book. Sometimes, however, this simple presentation of an idea has led to error, as when the author says, speaking of flounders, "they have the head so twisted that the two eyes occur both together on the uppermost side." The real status of the case is more remarkable and no harder to understand. But, considering it as a first edition, the book is remarkably free from errors.

L. M.

*D. Appleton & Co.

Books Received.

Student Life and Customs. By Henry D. Sheldon. D. Appleton & Co., New York, 1901. xxii and 366 pages. $1.20.

Educational Foundations of Trade and Industry. By Fabian Ware. D. Appleton & Co., New York, 1901. xiii and 300 pages. $1.20.

Laboratory Exercises in General Chemistry. By G. W. Shaw. American Book Company, 1901. 64 pages. 50 cents.

Herbarium and Plant Description. By W. H. D. Meier. Ginn & Co., 1901. 70 cents.

Reports of Meetings.

THE NEW YORK STATE SCIENCE TEACHERS' ASSOCIATION

Sixth Annual Meeting, Dec. 27-28, 1901.

For the third time in six years, the science teachers have met in Syracuse, through the courtesy of Syracuse University, which opened its medical college to the visitors. The success of the meeting was so gratifying that it was decided to meet in the same place in 1902.

The opening paper was by Dr. Samuel J. Saunders, of Hamilton College, on "The Value of Research Work in the Training of Science Teachers." An abstract will appear in SCHOOL SCIENCE. If space were available, a synopsis of the lively discussions elicited by this and other papers would be profitable.

The feature of the second session was the paper by Prof. N. A. Harvey, of Chicago, on "The Study of Types," an abstract of which, in three parts, is coming out in SCHOOL SCIENCE. The discussion was opened by Dr. Grant Karr, of Oswego Normal School.

The remaining hours of the afternoon, and most of the following morning, were devoted to section meetings, which are reported for this journal by the four section leaders.

There were no formal exercises in the evening. The members preferred to promote fellowship and acquaintance rather than to hear more speeches. After dining together at the Hotel Warner, they adjourned to the parlors and spent the evening socially, enjoying that leisure that many seek but few can find in a big convention.

At the brief general session following the section meetings on Sat-

urday morning, Dr. F. E. Lloyd, of Columbia University, presented "The Standard College Entrance in Botany," recently adopted by the Society for Plant Morphology and Physiology. Following this was a short symposium on the topic, "What ought the high school teacher in each science to know? What ought he to be able to do? What are his opportunities for self-improvement?" Dr. Lyman C. Newell, of Lowell, Mass., and Mr. Henry R. Linville, of New York, were the principal speakers.

At the closing session, Saturday afternoon, Prof. Irving P. Bishop, of Buffalo, read the report (of progress) of the Committee on Stimulants and Narcotics, summarizing the results of their investigation into the effects of the teaching of temperance as required by our state law. They believe that our law could be amended so as to be more acceptable to practical educators and to promise more satisfactory results. Following the report came the address of Prof. W. O. Atwater, of Wesleyan University, on "Alcohol Physiology in the Public Schools." After disclaiming any desire to have his own experiments taught in the schools while there is so much of greater importance to teach in the way of conclusions, he said:

"The amount of teaching of temperance physiology and the space given to it should be much less than is required by the legislation of a considerable number of states, including your own. The kind of teaching should be that which agrees most closely with the attested principles of physiological science; that which is both scientifically and pedagogically most reasonable."

He would have some of the time and space now devoted to alcohol physiology given to the subject of food and nutrition in general, since a large part of preventable disease is due to errors in diet.

After pointing out various mistakes in our temperance text books, he discussed the physiology of alcohol, and summed up his belief as follows: "It is, under some circumstances, a valuable nutriment, in the sense that it can yield energy to the body, but not in the sense that it can build tissue. It is, under other circumstances, a poison in the sense that it is injurious to health. When taken in large enough quantities and for long enough time it is destructive to life. It is sometimes very useful and sometimes very harmful, but the harm that comes from drinking, in many communities, vastly exceeds the good.

"While we cannot deny to alcohol a nutritive value, that value is very limited. In yielding energy to the body, it resembles sugar, starch and fat, though just how and to what extent it resembles them, experimental inquiry has not yet told us. It differs from them in that it does not require digestion, and is hence believed to be more easily and readily available to the body. It is not stored in the body for future use, like the nutrients of ordinary food materials. The quantity that may be advan-

tageously used is small. If large amounts are taken, its influence upon the nerves and brain are such as to counteract its nutritive effect, and it becomes injurious in various ways. And, finally, there are many people who begin by moderate use and are led to disastrous excess.

"Alcohol may be useful to one man and harmful to another. One may take considerable without apparent harm, while another may be injured by very little. One may use it habitually without injury, while another may not. In sickness it may be a priceless boon, but it may likewise be the cause of physical, mental and moral ruin. The boy or the man, as long as he is in good health and does not need alcohol for medicine, is, in general, better off without it."

He spoke of the repeal, by the last Connecticut legislature, of the former school physiology law, which, though less objectionable than those of some other states, including New York, was felt by nearly all the leading educators in the state to be too stringent. It was replaced by one requiring temperance instruction in a smaller number of grades and leaving the character of the text book and the instruction to the decision of the school authorities. This change was brought about by a fortunate co-operation of the teachers and temperance organizations of the state, including the state branch of the Woman's Christian Temperance Union; though it was vigorously opposed by Mrs. Hunt, of the Department of Scientific Temperance Instruction of the National W. C. T. U. The speaker believed that the example of Connecticut might well be followed in New York and other states.

In conclusion, Prof. Atwater said: "We wish to help the drunkard to reform; but is it necessary to tell him that no man can touch alcohol without danger? To build up the public sentiment upon which the reform of the future must depend, we wish our children to understand about alcohol and its terrible effects; but when we teach them in the name of science, shall we not teach them the simple facts which science attests, and which they can hereafter believe, rather than exaggerated theories, whose errors, when they learn them, will tend to undo the good we strive to do? In short, is not temperance advisable, even in the teaching of temperance doctrine?

"In the great effort to make men better, there is one thing that we must always seek, one thing we need never fear—the truth."

In the discussion, which lasted about an hour, Mrs. Hunt, who happened to be present, was allowed more time than any other speaker. She dwelt chiefly on the things that she has read about alcohol in her large library.

Mrs. Ella A. Boole, President of the New York State W. C. T. U., believed that it is "a reflection upon the teachers, that they have not presented the subject [physiological effects of alcoholics and narcotics] in such a way that it could be comprehended by the pupils." She attrib-

uted these results to the failure of normal schools and teachers' institutes "to impress the teachers that the object of this instruction is to make of the boys and girls intelligent total abstainers from liquor and tobacco."

Other members of the organization spoke, and the benches of the auditorium were well supplied with their literature. After remarks from several of the members, Prof. Bishop's report was accepted without a dissenting vote and his committee continued for another year.

The officers for 1902 are: President, Prof. William Hallock, Columbia University; Vice-President, Prof. Howard Lyon, Oneonta Normal School; Secretary-Treasurer, A. R. Warner, Auburn High School.

New members of the Council: Prof. Edward S. Babcock, Alfred University; Prof. H. J. Schmitz, Geneseo Normal School; William M. Bennett, Rochester High School.

Reported by F. W. BARROWS.

REPORT OF NATURE STUDY SECTION—STATE SCIENCE TEACHERS' ASSOCIATION.

December 27 to 28, 1902.

The program for this section was designed to bring out the opinions of those present on the training that a teacher should have in order to teach nature study. The first session was devoted to papers and discussion of these matters, and the second session to relating of personal experience by teachers actually engaged in carrying on nature-study work successfully in their schools.

The speakers were all present and the discussions were taken up with much vigor and interest. We agreed that the basis for successfully teaching nature study lies in an interest in the subject, a belief in its educational value in the broadest sense, and in a certain amount of personal experience with nature itself. That more training is desirable if added to the above essentials, was admitted by all.

Miss Hill, Miss Carss and Professor Bardwell showed how much could be done by trained nature students in the instructing of both children and teachers. But it was shown by Miss King, Miss Whittaker, Miss Mershon, Mr. Round and Mr. Drum that special science training is not absolutely necessary to carry out the spirit of true nature study.

Mr. Beach, in presenting his plan for teachers' classes, made practical suggestions, which recommended themselves to all. No doubt, many such classes will be formed during the coming year in cities. Mention was made of the Correspondence course for teachers, conducted by the Bureau of Nature Study at Cornell University. Teachers were urged to make use of every available opportunity to increase their knowledge of subject

matter, not in order that they may teach facts, but in order that they may teach their pupils how to learn from nature.

Reported by MARY ROGERS MILLER, Chairman.

NEW YORK STATE SCIENCE TEACHERS' ASSOCIATION.

The EARTH SCIENCE SECTION met on Friday afternoon, December 27, and on the morning of Saturday, December 28.

At the first session the subject for discussion was the question of "Geography for Training Students in the Normal Schools." Discussion was opened by four twenty-minute papers, given by Professor A. W. Farnham, of the Oswego State Normal School; Professor C. Stuart Gager, of the New York Normal College, Albany; Principal C. T. McFarlane, of the Brockport Normal School; and Professor W. S. Monroe, of the State Normal School, Westfield, Mass. The first two speakers paid particular attention to the work in physical geography that should be presented to normal students, who are intending to teach in the elementary schools; the last two speakers emphasized particularly the human side of the work as it should be presented, Professor Monroe outlining at some length what, to his mind, should be included in such a course in reference to the races of man, and their conditions and characteristics as related to their environment. All speakers agreed on the necessity of more time for geography work in the normal schools of New York State, and particularly for better co-ordination of the work, so as to secure more efficient geographical training.

The second session was devoted to the discussion of the preliminary report presented by the Committee of Seven, appointed in 1900, to outline a course in Physical Geography for the Secondary Schools of New York State. Mimeographed copies of the report of the Committee and of the course suggested by the Committee were in the hands of all who attended. After a brief presentation of the main points of view held by the Committee, the discussion was led by Head Inspector C. F. Wheelock, of the Regents Office; Professor A. P. Brigham, of Colgate University; and Miss Elizabeth Meserve, of the Free Academy, Utica. Informal discussion under a five-minute rule followed, and was participated in by many of those present.

Both sessions were particularly helpful and suggestive, and great interest was shown in the problems presented for discussion. At the close of the meeting, it was voted to ask the Association to continue the Committee of Seven for one year, with the expectation that they would, at the end of that time, present a series of laboratory exercises for Physical Geography in Secondary Schools, and a course of study for Elementary Schools.

Reported by RICHARD E. DODGE, Chairman.

PHYSICS AND CHEMISTRY AT THE NEW YORK STATE SCIENCE TEACHERS' ASSOCIATION.

The section devoted to Physics and Chemistry was in charge of Mr. J. M. Jamison, Pratt Institute, Brooklyn, N. Y. Two sessions were held and each was largely attended. At the first session, held on Friday afternoon, December 27, 1901, Professor Charles B. Thwing, Syracuse University, Syracuse, N. Y., read a paper on "The Preparation and Training of the Teacher of Physics," and Dr. Lyman C. Newell, State Normal School, Lowell, Mass., read a paper on "The Preparation and Training of the Teacher of Chemistry." At the session held on Saturday morning, December 28, 1901, Mr. R. J. Kittridge, Union Classical School, Schenectady, N. Y., read a paper on "The College Entrance Preparation of Students as Viewed from the Secondary Man's Standpoint," Professor Charles M. Allen, Pratt Institute, Brooklyn, N. Y., discussed "Chemical Laboratory Notes," and Mr. Frank M. Gilley read and illustrated a paper on "How to Meet the Problem of Teaching Physics by the Laboratory Method in Secondary Schools." A general discussion by members of the section followed each paper. According to an established custom, the papers and discussions will be published in full in the Proceedings. By kind permission of the Secretary and courtesy of the speakers, we are able to present to the readers of SCHOOL SCIENCE brief abstracts of the papers.

Professor Thwing's paper was developed along the following lines:

(1) The physics teacher should endeavor to attain to as accurate and broad a mastery, both theoretical and practical, of physics itself as lies within his range of power and opportunity. This presupposes a corresponding mastery of mathematics and implies some skill in practical mechanics.

Physics is, at least in its possibilities, the most exact of the natural sciences. The phenomena studied admit of accurate measurement and are reducible to laws which may be expressed in mathematical symbols.

The physics teacher should have, or seek to acquire, therefore, the habit of accuracy of thought. This habit will show itself in speech by the employment of exact terms and by the frequent use of such qualifying words as "about" and "approximately." It shows itself, too, in habits of promptness, order and neatness, and in manipulative skill, for the difference between a successful experiment and a failure depends oftentimes upon a turn of the wrist, while the ability to give the wrist the right turn at the right moment tells of a *habit* of accuracy which it has taken years to acquire.

(2) He should gain as wide a knowledge as possible of the related

sciences, especially chemistry, and seek to find the salient points of contact of the other sciences with physics.

(3) He should be a man among men, touching men at many points, helping and uplifting always, a man whose life embodies that strict conformity to the laws of being which his chosen science so perfectly exemplifies.

The following is a summary of Dr. Newell's paper:

(1) Teachers of chemistry need a broader, more uniform and more accurate knowledge of the fundamental facts and principles of chemistry. This is especially true at the present time because (*a*) the training in general chemistry received in many colleges is not suited for teaching in secondary schools, and (*b*) the teacher is apt to lose sight of the foundations in the multitude of facts which have been discovered in the last ten years. A convenient way to acquire knowledge of fundamentals is by reading a large text book.

(2) In order to teach chemistry a knowledge of other sciences is necessary. Interest in other sciences should be stimulated by reading scientific journals and attending meetings of scientific associations.

(3) The vital object of science teaching is to create and foster a scientific attitude of mind. No teacher can create and foster such scientific spirit, if he himself does not possess it. One of the best ways to acquire it is by doing original work. If such work is impossible, then the teacher should do some work having in it the element of originality, such as the simplification of apparatus or the improvement of some experiment. All teachers should write in order to acquire exactness of expression.

(4) The most important phase of teaching chemistry at the present time is the supervision of laboratory work. Failures in teaching are often traceable to a partial grasp of the psychology of laboratory work. In order to prevent shirking, such work must be carefully prepared and judiciously supervised, and must be searching enough to command respect, but not so difficult as to discourage. It must be followed up by questions. If the laboratory work is to relieve mental fatigue, the working period must not be too long or too short; opportunity must be given the pupils—especially girls—to sit down, the laboratory directions must not be too brief, long, or vague. The laboratory must not be left to run itself, nor should the pupil be given unlimited freedom. He should always be guided, but never told facts he can observe himself.

Pupils should be led from curiosity to interest, and by every possible device onward into the realm of voluntary attention. Quantitative work is best suited to teach voluntary attention.

Laboratory work should be so supervised that the pupil's mind can travel without needless inhibitions, i. e., interruptions, from the object of an experiment, through the manipulation, to the conclusion. Otherwise there will be loss of time and waste of mental energy.

(5) The teacher may learn these psychological principles by studying himself and his pupils. The teacher himself must pass through the gates of curiosity and interest into the temple of voluntary attention before he can lead others to the same spot.

Reported by LYMAN C. NEWELL.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

33. In one of the newer elementary text books in botany a statement is made that would lead one to believe that yeast can act on starch. On the other hand text books commonly give the impression that yeast can act only on sugar. Will someone please give the literature that will answer these questions? Is the ferment that changes the starch into some kind of sugar in the seed or flour, or does the yeast produce it?

Yeast does not act directly upon starch. Starch is readily hydrolyzed by the enzyme, diastase, which is produced by almost all plants. Diastase is present in all cells where starch is digested, and this must be done before it can be transferred from one point to another. The diastase may originate in the same cell as the starch grain, or it may diffuse in from adjacent cells. It breaks starch up into maltose and dextrine. The maltose is usually further decomposed into two parts of glucose, which may then be hydrolyzed by yeast. Yeast decomposes glucose and some other hexose sugars by excreting an enzyme, the *zymase* recently discovered by Buchner. On cane sugar it acts first by means of the enzyme, invertase, which breaks it up into glucose and fructose. These are then broken up by zymase into ethyl alcohol, carbon dioxide and other substances. (See Green's "The Soluble Ferments and Fermentation").

University of Chicago. C R BARNES.

34. Where can one obtain the sticks of Japanese incense for showing the path of rays of light mentioned in Dr. Porter's experiment in "Science," Oct. 11, 1901? It would also be useful for demonstrating currents in a room, in the study of hygiene.

The incense asked for may be obtained from any dealer in Japanese goods. The incense coiled in a spiral is probably better than the straight form. It is kept in Boston by Bunkio Matsuki and by Yamanaka & Co., both of whom are in Boylston street.

Physiological Laboratory, Harvard Medical School. W T. PORTER

35. Has anyone else observed anything like the following: One of our students brought in a piece of a weed stem on which were six or seven little paddles of ice, the fluted stem of the weed being the shafts or axis of the little paddle wheel thus formed. The plates of ice were about ⅛ of an inch thick, ⅜ wide and 1½ inches long. An explanation will be welcome

See Lester F. Ward on "Frost Freaks of the Dittany," in Botanical Gazette, XVIII, 183-186, Pl. 19, 1893; and George F. Atkinson on "Frost Freaks of Herbaceous Plants," *ibid*, XIX, 40-42, 1894.

University of Chicago. C. R. BARNES.

REPRINTS OF SCIENCE CLASSICS

No. 1.

THE

ANALYSIS OF AIR AND WATER

BEING SELECTIONS FROM

LAVOISIER'S ELEMENTARY TREATISE OF CHEMISTRY

TRANSLATED AND ANNOTATED

BY

C. E. LINEBARGER

DOUBLE NUMBER. TEN CENTS.

1902.

Ravenswood, Chicago, Ill.

The School Science Press.

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C. E. LINEBARGER.

BIOGRAPHICAL SKETCH.

ANTOINE LAURENT LAVOISIER was born the 16th of August, 1743, in Paris. He received an excellent education, and early showed an aptitude for the study of science. When only twenty-two years of age, he was awarded a prize for having elaborated the best plan for lighting the streets of his native city, and it is related that in the preparation of this plan, he spent six weeks shut up in a darkened room, so as to render his perception of the differences in the intensities and natures of various sources of light more acute. In his twenty-eighth year he was appointed to a high official position, that of farmer general or collector of taxes, which gave him the needed wealth and leisure for carrying on his scientific researches. He occupied himself actively with the scientific questions of the time, and by his brilliant experiments overthrew the Doctrine of Phlogiston, which had reigned undisputed for more than a century.

Lavoisier is to be regarded as the originator of new ideas and conceptions, rather than the discoverer of new facts. He was the first to insist upon the rigorous application of the balance to chemical problems, and was the propounder of the Law of the Conservation of Matter.

Lavoisier perished on the guillotine the 8th of May, 1794, at the hands of the French Revolutionists, his only "crime" being that he was an aristocrat.

AN
ELEMENTARY TREATISE
OF
CHEMISTRY.

CHAPTER III.

The analysis of the air[1] *of the atmosphere; its resolution into two elastic fluids*[2]*, the one respirable, the other non-respirable.*

Our atmosphere is a mixture of all the substances capable of remaining in a gaseous state under the ordinary conditions of temperature and pressure. These fluids form a mass of very nearly homogeneous nature, extending from the surface of the earth to the highest altitudes, the density decreasing with the altitude.

We now propose to ascertain what is the number and nature of the elastic fluids composing the lower layers of the atmosphere, and to that end we shall employ experimental means. In this regard modern chemistry has made great strides in advance; the details into which I shall enter will show that the air of the atmosphere is perhaps of all the substances of this kind the one whose analysis can be carried out with the greatest accuracy and exactness. Generally speaking, there are two ways in chemistry of finding out the nature of the constituents of a body, one by composition, the other by de-

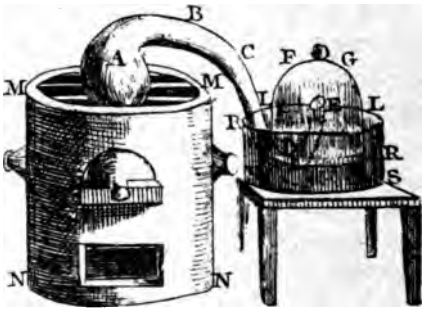
composition[3]. For example, if we mix water and alcohol and thus obtain a kind of liquor known as brandy[4], we have a right to conclude that brandy is a compound of alcohol and water; but we may arrive at the same conclusion by way of decomposition, and, speaking generally, we should in chemistry never be quite satisfied until we have combined both of these proofs.

In the analysis of the air of the atmosphere, we have the advantage of being able both to decompose and to re-compose it; and I shall limit myself to the description of the experiments which are the most conclusive in this respect. There is hardly one of them that is not original with me, either in that I was the first to perform it, or in that I repeated it according to a new point of view, *viz.*, that of the analysis of the air of the atmosphere.

I took a matrass A of about thirty-six cubic inches[5]

Fig 14

Fig 2



capacity, (Fig. 14), whose neck BCDE, was very long and had a bore of six to seven lines[5]. I bent it, as shown in Figure 2, so that it could be placed in a furnace MMNN, while the extremity E of its neck projected up into the bell jar FG, set in a mercury bath RRSS. I introduced into the matrass

four ounces[5] of very pure mercury, and then by suction through a siphon, which I placed under the bell jar FG, I caused the mercury to rise up to LL. I marked this position very carefully with a strip of gummed paper and read the barometer and thermometer.

Everything being thus in readiness, I lighted the fire in the furnace MMNN, and kept it going for twelve days, so that the mercury was always very near its boiling point.

Nothing of note occurred during the first day; the mercury, although not actually boiling, was in a state of continual evaporation; it covered the interior of the vessels with droplets, very small at first, which continually increased in size, until, when of a certain volume, they fell back to the bottom of the matrass to mingle with the rest of the mercury. The second day I commenced to see little red particles[6] swimming over the surface of the mercury, which during four or five days increased in number and volume; they then stopped increasing and remained in absolutely the same condition. At the expiration of twelve days, seeing that the calcination[7] of the mercury made no further progress, I put out the fire and let the vessels cool. The volume of the air in the matrass, in its neck and in the empty part of the bell jar, when reduced to 28 inches of mercury and 10 degrees of the thermometer, was about 50 cubic inches before the experiment. When the experiment was finished, the volume reduced to the same pressure and temperature was found to be from 42 to 43 cubic inches. There was a diminution of volume amounting to about a sixth. The red particles which had formed were carefully collected and separated as completely as possible from the mercury; their weight was found to be 45 grains[8].

I was obliged to repeat this calcination of mercury in closed vessels several times, because it is difficult in one and the same experiment to measure both the air and the red par-

ticles which had formed. It will therefore happen quite often that the results of two or more experiments will be combined in one account.

The air which remained after this operation and which had been reduced to five-sixths of its original volume was no longer respirable nor combustible, for animals introduced into it died in a short time, and a light was immediately extinguished, as if it had been plunged under water.

I put the 45 grains of the red substance, which was formed in the operation, into a very small glass retort, to which was connected an apparatus arranged to receive the liquid and aëriform products that might separate from it. After lighting the fire in the furnace, I noticed that as the red substance became heated its color deepened. As soon as the retort was red hot, the substance commenced to diminish in volume, little by little, until in a few minutes it disappeared completely. At the same time 41½ grains of mercury condensed in the small receiver, and there passed into the receiver 7 to 8 cubic inches of an elastic fluid which supported combustion and respiration much more vigorously than the air of the atmosphere.

When a portion of this air was passed into a glass tube about an inch in diameter, and a candle was introduced, it burned with blinding brilliancy. Charcoal, instead of burning quietly as in ordinary air, burst into flame, like phosphorus, and the light was so strong that the eyes could hardly stand it. This air, which Priestley, Scheele and myself[8] discovered at almost the same time, was called dephlogisticated air[9] by the former and empyreal air[10] by the latter. I at first gave it the name of *eminently respirable air,* for which was substituted later that of *vital air.* We shall take up the consideration of these names later.

A consideration of the conditions of these experiments shows that the mercury in its calcination absorbs the salubrious

and respirable part of the air, or, speaking more rigorously, the base[11] of this respirable part; that the portion of the air remaining is incapable of supporting combustion or respiration; and that the air of the atmosphere is therefore made up of two elastic fluids of a different and even opposite nature.

A proof of this important truth is that, if we re-combine the two elastic fluids thus obtained separately, that is, the 42 cubic inches of non-respirable air and the 8 cubic inches of respirable air, we can re-form an air which is in every respect similar to that of the atmosphere, and is almost as well adapted for combustion, respiration and the calcination of metals.

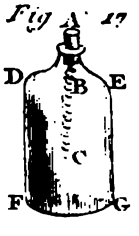
Although this experiment furnishes an exceedingly simple method of separating the two principal elastic fluids of the atmosphere, it does not give us an exact idea as to the proportion of these two fluids. The affinity of mercury for the respirable portion of the air, or rather its base[11], is not sufficient to overcome the obstacles opposing this combination. These obstacles are the adherence of the two fluid constituents of the air of the atmosphere and the force of affinity which unites the base of vital air with caloric[11]. Consequently when the calcination of mercury is finished, or at least carried as far as possible in a given amount of air, there still remains a little respirable air combined with the non-respirable air, and mercury is unable to effect the separation of this last portion. I shall show later that the proportion of respirable air to non-respirable air, as they are found in the air of the atmosphere, is in the ratio[12] of 27 to 73, at least in the climates which we inhabit; I shall discuss at the same time the causes of the uncertainty still existing in regard to the exactness of this proportion.

Inasmuch as the air is decomposed in the calcination of mercury with fixation[13] and combination of the base of its respirable part with the mercury, it follows from the princi-

ples which I have already exposed, that caloric and light should be set free, and there can be no doubt but that this is actually the case; but two causes prevent its being manifested in the experiment which I have just described. The first is that inasmuch as the calcination lasts several days, the evolution of heat and light is spread out over so long an interval of time that it is extremely feeble at each particular instant; the second is that inasmuch as the operation is carried out in a furnace, the heat due to the calcination is masked by that of the furnace. I might add that the respirable part of the air, or rather its base, does not, in combining with mercury, lose all the caloric that was in combination with it, but that part of it remains in the new compound; but this discussion and the proofs which I would be obliged to cite would not be in place here.

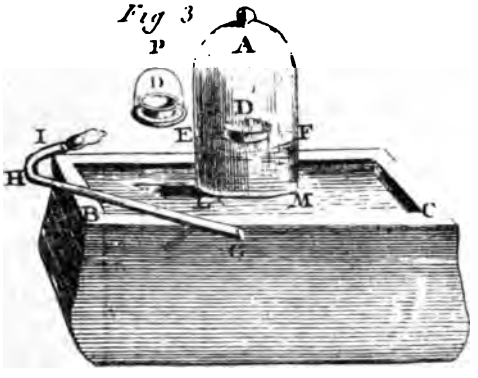
It is, however, very easy to make the evolution of heat and light manifest by effecting the decomposition of air more rapidly. Iron, which has much more affinity for the base of the respirable portion of the air than has mercury, furnishes the means thereto. One end of a fine wire BC (Fig. 17) is twisted into a spiral, and the other end B fastened to a cork fitting the bottle DEFG. A little tinder is attached to the twisted extremity of the wire. The bottle DEFG is filled with air deprived of its non-respirable portion. The tinder is ignited, and, together with the iron wire BC, promptly plunged into the bottle, which is then closed, as shown in the figure that I have just mentioned. As soon as the tinder is introduced into the vital air, it commences to burn with blinding brilliancy; it sets the iron on fire, which, while burning, throws off brilliant sparks that fall to the bottom of the bottle in rounded globules, which become black when cool, and then present a luster approaching

Fig. 17.



that of metals. Iron which has been burnt in this manner is more fragile and brittle even than glass; it may be reduced readily to a powder, and is still attracted by a magnet, although less so than before its combustion.

I filled a bell jar (Fig. 3), of about six pints capacity, with



pure air, that is to say, with the eminently respirable portion of the air. With the aid of a very shallow vessel, I transferred this jar to a mercury bath contained in the basin BC. I then carefully dried with bibulous paper the surface of the mercury, both inside and outside the jar. Having provided myself with a small porcelain capsule D, I placed in it some thin strips of iron, twisted in a spiral form, and arranged them so that the combustion could readily spread through the entire mass. I fastened a bit of tinder to the end of one of the spirals and added a fragment of phosphorus weighing scarcely a sixth of a grain. I introduced the capsule under the jar by raising it up a little. I am not unaware that by such a procedure a small amount of common air may enter and mix with the air in the jar; but this admixture is so slight, when one is care-

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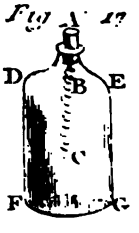

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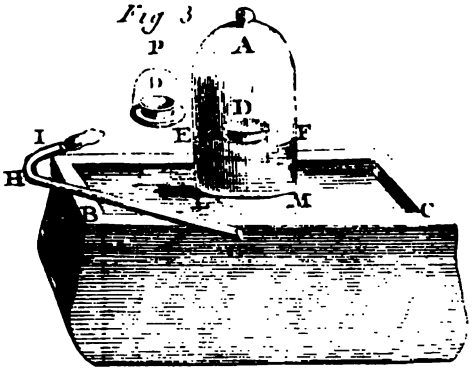

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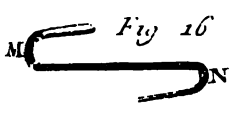
ful, that it does not at all interfere with the success of the experiment.

After the capsule D is introduced into the jar, part of the air it contains is removed by suction so as to raise the level of the mercury up to EF; a siphon GHI is used for this purpose, which is slipped under the jar and which has a bit of paper twisted around the end to prevent its becoming filled with mercury. It requires some little address to raise the level of the mercury in this way by suction; if the air is drawn out by the action of the lungs alone, it is not possible to obtain but a slight elevation, as, for example, an inch or an inch and a half at the most, while by the action of the muscles of the mouth the level can be raised without difficulty six or seven inches.

When everything is in readiness, a bent piece of iron MN (Fig. 16), fashioned for this kind of an experiment, is heated to redness in a fire. It is then passed under the jar, and before it has time to cool off it is brought close to the little piece of phosphorus contained in the porcelain capsule D. The phosphorus takes fire at once and ignites the tinder, which, in turn, ignites the iron. If the spirals have been properly arranged, all the iron burns to the last atom[14], giving out a brilliant, white light, similar to that observed in certain Chinese fire-works. The great heat generated during the combustion melts the iron, which falls in round globules of different sizes to the bottom of the capsule, although some are thrown out and float on the surface of the mercury. At the commencement of the combustion there is a slight increase in the volume of the air because of the expansion caused by the heat; but a rapid decrease in volume soon succeeds this increase, and the mercury rises in the jar. When there is sufficient iron, and the air taken is very pure, nearly all of it is absorbed.



I should state here that it is not well to use too much iron. When the experiment has proceeded so far that most of the air is absorbed, the capsule D, floating upon the mercury, approaches so close to the top of the jar that the great heat, together with the sudden chilling due to contact with the mercury, may break the glass, and the weight of the mercury, which rapidly falls if the glass should crack, causes a large part of the liquid to flow over the sides of the trough. To avoid this and to insure the success of the experiment, not more than a *gros*[15] and a half of iron should be burnt in a jar of eight pints capacity. The jar must also be strong enough to withstand the weight of the mercury it is intended to contain.

In this experiment it is not possible to determine at one and the same time the increase in the weight of the iron and the changes which the air undergoes. If the increase in the weight of the iron and its relation to the quantity of air absorbed is to be found, the level of the mercury before and after the operation should be marked very accurately on the bell jar with a diamond. The siphon GH (Fig. 3) is covered at one end with a piece of paper to prevent its becoming filled with mercury, and, with the thumb pressed over the other end G, it is passed under the jar. By moving the thumb aside a little, air can be admitted gradually. When the mercury inside has fallen to the level of that outside, the jar is removed gently, and the globules of iron contained it it, as well as those floating on the mercury, are carefully collected and weighed. This iron has a sort of metallic luster, is very brittle and friable, and may be readily reduced to a powder under the hammer or pestle. In a successful operation, 100 grains of iron will yield 135 to 136 grains of this substance.

If this experiment be given all the attention it merits, it will be seen that the diminution in the weight of the air is exactly equal to the increase in the weight of the iron [16]. If

then 100 grains of iron are burnt and the increase in the weight of the metal is 35 grains, the diminution of the volume of the air is almost exactly 70 cubic inches, so that half a grain of air occupies one cubic inch. Later we shall show that the weight of a cubic inch of air is almost exactly half a grain.

I will call to mind again, and for the last time, that in all experiments of this kind, the volume of the air at the beginning and at the end of the experiment should always be reduced by calculation to that which it would occupy at 10 degrees of the thermometer and at a pressure of 28 inches of mercury. I shall discuss in some detail the method of making these corrections at the end of this work.

If the quality of the air remaining in the jar is to be examined into, the operations are somewhat different. After the combustion is finished and the vessels are cool, the iron and the capsule containing it are removed by thrusting the hand up through the mercury into the jar. Then potash or caustic alkali, dissolved in water, or potassium sulphide, or any other substance whose action upon the air is to be investigated, is introduced into the jar. Later I shall revert to these methods of analyzing the air and will describe the properties of these substances, which I now mention but incidentally. Finally enough water is introduced under the same bell jar to displace all of the mercury, a plate or other shallow vessel passed under it, and the whole transferred to a pneumatic trough, where any experiments can be performed on a larger scale and with more facility.

When the iron employed is very soft and pure, and the respirable portion of the air is free from any admixture of non-respirable air, the air remaining after the combustion is still just as pure as it was before the combustion; but it is rare that the iron is exempt from a small amount of carbonaceous material; steel, in particular, always contains some. It is also

extremely difficult to obtain the respirable portion of the air perfectly pure; it is nearly always mixed with a small proportion of non-respirable air, which, however, does not interfere with the result of the experiment, and is found in the same quantity at the end of the experiment as at its commencement.

I stated above that the nature of the constituent parts of the air of the atmosphere could be determined according to two methods; by way of decomposition and by way of composition. The calcination of mercury offers an example of both these methods, for, after having removed the respirable part of the air by heating it with mercury, we have restored it again so as to form an air in every respect similar to that of the atmosphere. But we can also effect such a decomposition of atmospheric air by deriving from the different kingdoms of nature the materials forming it. We shall see later that when animal substances are dissolved in nitric acid, a large quantity of an air is evolved which extinguishes flames, suffocates animals, and is similar in all respects to the non-respirable portion of atmospheric air. If to 73 parts of this elastic fluid, 27 parts of eminently respirable air, derived from mercury which has been converted into a red calx[7] by heating, are added, an elastic fluid is obtained which is perfectly similar to that of the atmosphere and exhibits all of its properties.

There are many other methods of separating the respirable part of the air from the non-respirable part; but I could not consider them here without assuming a knowledge of things that properly belong in the following chapters. Also the experiments which I have described suffice for an Elementary Treatise, for in such matters as these the choice of proofs is more important than their number.

CHAPTER IV.

Nomenclature of the different constituents of the air of the atmosphere.

In what precedes, I have been under the necessity of using circumlocution in speaking of the nature of the different substances composing our atmosphere, and I adopted provisionally the expressions, *respirable part* and *non-respirable part of the air*. The details into which I shall now enter require me to proceed more rapidly, and so, after having given some simple notions of the different substances composing atmospheric air, I shall also express them in simple words.

We have not thought it advisable to change the names that have been current and well known for a long time. We have accordingly given to the words, *water* and *ice*[17], their common signification, and we have likewise denoted by the word, *air*, the collection of elastic fluids composing our atmosphere; but we have not believed that the same respect must needs be shown to the terms proposed very recently by physicists. We have thought that we had a perfect right to reject them and to put in their place other terms less liable to lead into error, and even when we have concluded to adopt those of recent origin, we have not hesitated to modify them and attach to them notions which are more clearly defined and better circumscribed.

We have derived the new words principally from the Greek and have tried to make their etymology recall the things which they denote, and we have been especially careful not to admit, in so far as it was possible, any but short words which could easily form verbs and adjectives.

In accordance with these principles, we have retained the name *gas*, first employed by von Helmont, and have included under that head all aëriform elastic fluids except the air of the atmosphere. The word *gas* is, therefore, a generic name, denoting the extreme degree of saturation of a substance by caloric[11]: it is the expression of a particular condition of a substance. It was then necessary to specify each kind of gas, and we have succeeded in doing this by adding a second word derived from that of the base[11]. We shall accordingly call water, combined with caloric and in the condition of an aëriform fluid, aqueous gas; the compound of ether with caloric shall be ethereal gas; that of spirits of wine with caloric shall be alcoholic gas. In the same fashion we shall have muriatic acid gas, ammoniacal gas, and so forth. I will dwell more at length upon this point when the nomenclature of the different bases comes up.

We have seen that the air of the atmosphere is composed principally of two aëriform fluids of gases, one of which is respirable, supports the life of animals, the calcination[7] of metals and the burning of combustibles, while the other has absolutely opposite properties, neither supporting the respiration of animals nor combustion, etc. We have given to the base of the respirable portion of the air the name of oxygen, deriving it from the two Greek words, ὀξύς, *acid*, and γεννάω, *I produce*, because one of the most general properties of this base is its combining with many other substances to form acids. We shall accordingly apply the name of oxygen gas to the compound of this base with caloric. Its weight in this condition is almost exactly a half-grain[5] per cubic inch, or an ounce and a half per cubic foot, all at 10 degrees of temperature and 28 inches of mercury.

The chemical properties of the non-respirable part of the air not being as yet very well known, we had to content our-

selves with the name of its base from the property the gas has of depriving animals of their life; we have accordingly called it azote, from the *ἀ* privative of the Greeks and *ζωὴ*, *life*. The non-respirable part of the air shall therefore be called azotic gas. Its weight is one ounce[5], 2 *gros*[16], 48 grains per cubic foot, or 0.4444 grain per cubic inch.

We do not pretend to deny that this name is rather singular, but such is the lot of all new names, and it takes some time for their novelty and strangeness to wear off. We have, indeed, searched a long time for a better name, but have been unable to find it. We at first thought that we would call it the alkaligenous gas, because it has been proved by the experiments of Berthollet that this gas enters into the composition of the volatile alkali or ammonia. But, on the other hand, we have not yet the proof that it is one of the principal constituents of the other alkalies. Also, inasmuch as it enters into the composition of nitric acid, we would have just as much of a right to call it the nitrogenous principle. So we were compelled to reject every name that would convey the idea of a system, and thought that the safest way to avoid error would be to adopt the name of azote and azotic gas, which simply express a fact, or rather the property that this gas has to deprive animals which breathe it of their life.

If I should dwell more at length upon the nomenclature of the different kinds of gases, I would anticipate certain topics that are reserved for subsequent chapters. It seems to be sufficient that here be given, not the names of all the gases, but simply the method of naming them all. The merit of the nomenclature which we have adopted consists principally in this: after the simple substance is named, the names of all of its compounds are necessarily derived from this first word.

CHAPTER VIII.

The principal radical[18] *of water, and the decomposition of water by charcoal and by iron.*

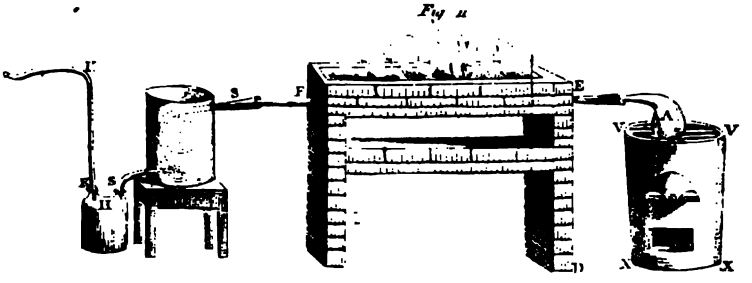
Until very recent times water was considered to be a simple substance, and the ancients regarded it as an element because they were unable to decompose it, or, rather, because the decompositions of water, which are continually taking place in nature, had escaped their observation; but we shall see that water can no longer be looked upon as an element. I shall not here enter into the history of this discovery, which is very modern and which is still questioned by some. The Mémoires de l'Academie des Sciences of 1781 may be consulted for information on this point.

I shall content myself with giving the principal proofs of the decomposition, as well as re-composition of water: and I venture to say that anyone who will take the pains to consider them without partiality, will find them conclusive.

FIRST EXPERIMENT.

Preparation.

A glass tube EF (Fig. 11), 8 to 12 lines in diameter, is placed in a furnace so as to be inclined a little from E to F. To the higher extremity E of this tube is joined a glass retort A, which contains a known quantity of distilled water, and to its lower end F is attached a worm SS′ engaging at S in the neck of a bottle H with two tubulatures, in one of which fits a bent glass tube KK, designed to conduct the aëriform



fluids or gases into an apparatus where their quantity and quality may be determined.

To insure the success of this experiment it is necessary that the tube EF be made of a difficultly fusible and well annealed glass. Outside it is covered with a clay lute, mixed with a cement made from powdered earthenware. To prevent its bending when softened by heat, it is supported in the middle by an iron bar placed across the furnace. Porcelain tubes are preferable to glass ones, but it is hard to get any that are not porous, and nearly always chinks occur in them through which air or vapors may pass.

When everything has been thus arranged, the fire is lighted in the furnace EFCD and kept up so as to heat to redness the glass tube EF without melting it. At the same time a fire is kindled in the furnace VVXX, so as to keep the water boiling in the retort A.

Effect.

As the water vaporizes in the retort A, it fills the interior of the tube EF and drives out the common air, which escapes from the tube KK; the aqueous gas is then condensed in passing through the worm SS, and the water drops into the tubulated bottle H.

If this operation be continued until all the water in the retort A is evaporated, and the vessels are well drained of their contents, a quantity of water is found in the bottle H, which is exactly equal to that which was in the retort A, and no evolution of gas has taken place. This operation then is nothing but an ordinary distillation, the result of which is absolutely the same as it would have been even though the water had not been heated to incandescence in passing through the tube EF.

SECOND EXPERIMENT.

Preparation.

The apparatus is set up just as in the preceding experiment with this sole difference that twenty-eight grains of charcoal broken up into pieces of moderate size and previously heated to incandescence for some time in a closed vessel, are placed in the tube EF.

Effect.

The water in the retort A distils just as it did in the preceding experiment; it condenses in the worm and runs drop by drop into the bottle H; but at the same time a considerable quantity of gas is evolved, which escapes by the tube KK and may be collected by means of a suitable apparatus.

At the end of the operation only a few atoms[14] of cinders are left in the tube EF; the twenty-eight grains of charcoal have totally disappeared.

The gases evolved, when examined with care, were found to weigh altogether 113.7 grains; they are of two kinds, 144 cubic inches of carbonic acid gas, weighing 100 grains, and 380 cubic inches of an extremely light gas which weighs 13.7 grains, and in contact with air, takes fire when a burning substance is

brought to it. The weight of the water in the bottle is 85.7 grains less than that originally present in the retort.

In this experiment, then, 85.7 grains of water plus 28 grains of charcoal have produced 100 grains of carbonic acid gas plus 13.7 grains of a gas burning with great ease.

But I have already shown that 100 grains of carbonic acid gas results from the union of 72 grains of oxygen and 28 grains of charcoal. The 28 grains of charcoal placed in the glass tube have therefore removed 72 grains of oxygen from the water, and 85.7 grains of water is composed of 72 grains of oxygen and 13.7 grains of an inflammable gas. We shall soon see that this gas cannot be supposed to be evolved from the charcoal, and that it must come from the water.

In the account of this experiment I have suppressed certain details which would only complicate it and obscure the ideas of the reader. The changes in the quantities thus occasioned are inconsiderable, but it seemed best to allow for them in the calculations and thus to present the results of the experiment in all their simplicity. If, however, any doubts remain as to the truth of the results from this experiment, they will soon be dissipated by other experiments which I now proceed to describe.

THIRD EXPERIMENT.

Preparation.

The apparatus is set up as in the preceding experiments with the exception of the substitution for the 28 grains of charcoal of 274 grains of very soft iron, cut into strips and rolled into spirals. The tube is heated to redness, as in the preceding experiments; a fire is lighted under the retort A, and the water is kept boiling constantly until it is completely evaporated, passed through the tube EF and condensed in the bottle H.

Effect.

No carbonic acid gas is generated in this experiment, only an inflammable gas 13 times lighter than atmospheric air. The weight of all that was obtained of it is 15 grains and its volume is about 416 cubic inches. A comparison of the quantity of water originally taken with that found in the bottle H, shows a deficit of 100 grains. On the other hand, the 274 grains of iron placed in the tube EF weigh 85 grains more than when they were introduced, and their volume is considerably increased. This iron is but feebly attracted by a magnet, dissolves in acids without effervescence, and, in a word, is the black oxide of iron, precisely the same as that obtained by burning iron in oxygen.

Reflections.

The result of this experiment shows that the iron has been oxidized by the water—an oxidation exactly like that which takes place in the air when iron is heated. One hundred grains of water have been decomposed; 85 grains of oxygen have united with the iron to form the black oxide of iron, and 15 grains of a peculiar, inflammable gas have been evolved. Water is therefore composed of oxygen and of the base[11] of an inflammable gas in the proportions of 85 to 15.

Water, therefore, besides the oxygen which is one of its principles, as well as that of many other substances, also contains another principle which is peculiar to it, which is its constitutive radical[12] and to which we find ourselves forced to give a name. None has seemed so appropriate to us as hydrogen, that is to say, the generating principal of water, from ὕδωρ, *water* and γεννάω, *I generate*. We shall give the name of hydrogen gas to the compound of this principle and caloric, and the word *hydrogen*, standing alone, shall designate the base of the same

gas, the radical of water.* Here, then, is a new, combustible substance, that is to say, a substance which has enough affinity for oxygen to remove caloric from it and to decompose water. This substance has so great an affinity for caloric that, unless it is in combination, it is always in the gaseous state under the ordinary conditions of pressure and temperature. As a gas it is about 13 times lighter than the air of the atmosphere; it is not at all soluble in water, and it does not support the respiration of animals.

The property of taking fire and burning being for this gas as for all other combustibles, nothing but the property of decomposing the air and separating oxygen from caloric, it is readily seen why it cannot burn except in contact with air or oxygen. Thus, when a bottle is filled with this gas and it is ignited, it burns gently at the mouth of the bottle and the flame gradually passes into the bottle as the external air enters; but the combustion is slow and takes place only at the surface separating the two airs or gases. A different behavior is observed, however, when the two airs are mixed before they are ignited. If, for example, one volume of oxygen be mixed with two volumes of hydrogen in a narrow-mouthed bottle and a burning substance, such as a lighted candle or piece of paper, be brought to the mouth of the bottle, the combustion of the gas takes place instantaneously with a loud explosion. This experiment should always be carried out in a very strong bottle of green glass not holding over a pint, which should be well wrapped up in a cloth. Otherwise there is danger of accident from the bursting of the bottle, the fragments of which may be projected to a considerable distance.

* The name of *hydrogen* has been criticized even with some bitterness on the ground that it may mean produced from water as well as producer of water. But what does that matter, if the expression is equally appropriate in both senses? The experiments described prove that the decomposition of water gives rise to hydrogen, and especially that hydrogen generates water in combining with oxygen. It is just as well to say that water produces hydrogen as that hydrogen produces water.

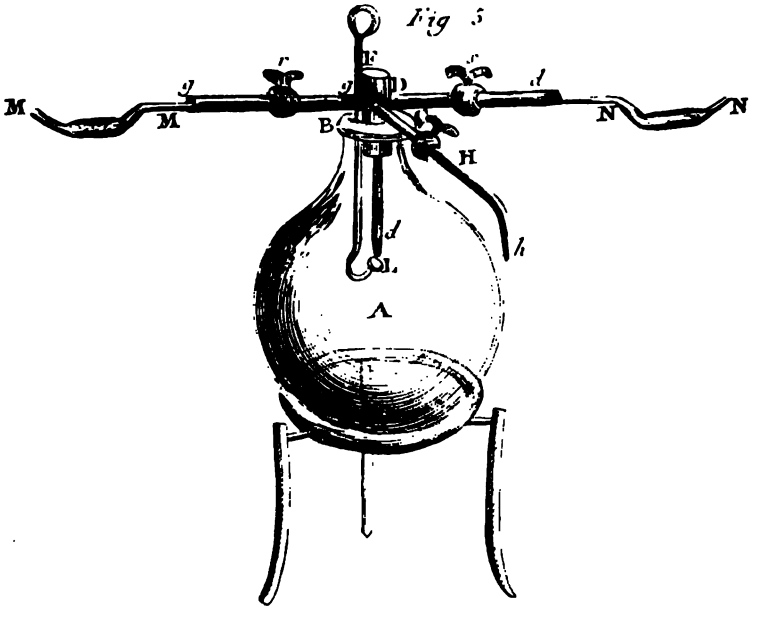
If all that I have just set forth about the decomposition of water is exact and true, if this substance is really composed, as I have endeavored to prove, of a peculiar principle, hydrogen, combined with oxygen, then it ought to follow that by re-combining these two principles, water should be re-formed, a conclusion quite in accordance with fact, as will be shown in the following experiment.

FOURTH EXPERIMENT.

Preparation.

A round bottomed glass flask A (Fig. 5) of about 30 pints capacity, has cemented over its wide mouth a copper cover BC pierced with four holes in which terminate four tubes. The first H*h* of these tubes is arranged so that it can be connected at *h* with an air pump by means of which a vacuum can be

Fig 5



created inside the flask. A second tube *gg* communicates at MM with a reservoir of oxygen gas and is so constructed that the gas can be conducted into the flask. A third tube *d*D communicates at *d*NN with a reservoir of hydrogen gas; the inner extremity of this tube has a very small opening hardly large enough for a very fine needle to enter. The hydrogen escapes by this fine opening, and to impart to it a sufficient velocity, it is subjected to a pressure of from one to two inches of water. Finally, the cover BC is pierced with a fourth hole in which is cemented a glass tube through which passes a metal wire GL at the extremity L of which is fastened a little ball so adjusted that an electric spark can be made to pass from L to *d* and thus ignite the hydrogen gas, as we shall soon see. The metallic wire GL moves easily up and down in the glass tube so that the ball may be separated from the extremity *d*. All three tubes, *d*, D*d*, *gg*, H*h* are each provided with a stop-cock.

In order to be certain that the hydrogen gas and the oxygen gas are quite dry when they arrive at the tubes which conduct them into the flask A, they are made to pass through the tubes MM, NN, of about an inch in diameter, which are filled with some deliquescent salt such as the acetate of potash, the muriate or nitrate of lime. *Consult* the second part of this Work for the composition of these salts. They should be in the form of a coarse powder so that they will not run together and clog up the tubes.

A sufficient supply of well-purified oxygen should have been provided for, and in order to be sure that it does not contain any carbonic acid, it should be left for some time over a strong solution of caustic potash.

With like care twice as much hydrogen gas is prepared. The surest way to get it without any admixture is to prepare it by the decomposition of water by very ductile and pure iron.

When the two gases are ready the air pump is connected to the tube H*h* and a vacuum made in the large flask A. One or the other of the two gases is then conducted into it, but preferably the oxygen gas by the tube *gg*; then by a suitable adjustment of the pressure, hydrogen gas is made to enter by the tube *dDd*, of which the extremity *d* terminates in a point. Finally this gas is lighted with the aid of an electric spark. By passing into the flask each of the gases or airs, the combustion may be kept up for a very long time. I have given in another place a description of the apparatus which I have employed for this experiment, and I have explained in what manner the volumes of the gases consumed could be measured with vigorous exactness. *Consult* the third part of this Work.

Effect.

As the combustion proceeds, water is deposited upon the inside walls of the flask or matrass; the quantity of this water increases little by little; it runs together in large drops which collect in the bottom of the flask.

By weighing the matrass before and after the operation, it is easy to ascertain the amount of water collected. This experiment affords us then a double verification; the weights of the gases employed, and the weight of the water formed. In an experiment of this kind M. Meusnier and I found that 85 parts by weight of oxygen and 15 parts of hydrogen were required to form 100 parts of water. This determination, which has not yet been published, was performed in the presence of a large committee of the Academy; we gave it the most careful attention and we believe it to be exact to within a two-hundredth[20].

Thus, operating either by way of decomposition or of recomposition, we have a right to regard the result as constant, and as well proved as anything can be in chemistry or physics,

viz.: that water is not a simple substance; that it is composed of two principles—oxygen and hydrogen—and that these two principles have such an affinity for caloric that they cannot exist free except as gases under the conditions of temperature and pressure we live in.

This phenomenon of the decomposition and re-composition of water is taking place continually right under our eyes. As we shall soon see, the phenomena of vinous fermentation, of putrefaction and even of vegetation is, to a certain degree, due to this decomposition, and it seems extraordinary that this point has until now escaped the attention of physicists and chemists. We may perhaps draw the conclusion that in matters of science, as well as of morals, it is hard to overcome the prejudices which have been imbibed and to follow a path differing from the one we have been accustomed to travel.

NOTES.

This translation is made from the second edition of Lavoisier's *Traité Elémentaire de Chimie*, dated 1793. It is as literal as possible and but few liberties are taken with the text.

The selections are such as will give a good idea of some of the principal achievements of Lavoisier in chemistry. Lavoisier's own account of the first analysis of atmospheric air, which is given in a condensed form in many texts on chemistry, cannot fail to impress and interest the reader. The chapter on nomenclature gives a notion of the fundamental principles of naming things, which should be known by everyone, and the account of the analysis of water is admirable in its experimental plan, its strictness of logic and conclusiveness of results. It is believed that the beginner in chemistry will gain much benefit from the study of these selections, so different in style and treatment from the usual run of the text books of today.

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(1). What are now called gases were formerly called "airs." All gases were supposed to be but modifications of atmospheric air, or to be atmospheric air mixed with various vapors or exhalations. It was customary to distinguish different kinds of "airs" by some adjective, as "fixed air" (carbon dioxide), "vital air" (oxygen), "atmospheric air," etc.

(2). "Elastic fluid" is synonymous with gas or vapor.

(3). Or, as we now say, synthesis and analysis.

(4). We would not say today that brandy is a chemical compound, for there is no definiteness in the proportions of the alcohol, water, etc., composing it. The law of definite proportions was not enunciated until some years after Lavoisier's death.

(5). The weights and measures of the old French system, which are used in this reprint, are given below, with their metric equivalents and translation into English:

1 ligne (line) equals 2.2558 millimeters.
1 pouce (inch) equals 12 lignes equals 27.0696 millimeters.
1 pied (foot) equals 12 pouces equals 32.4835 centimeters.
1 pinte (pint) equals 931 cubic centimeters.
1 grain (grain) equals 0.0532 gram.
1 gros (gros) equals 72 grains equals 3.8304 grams.
1 once (ounce) equals 30.6432 grams.

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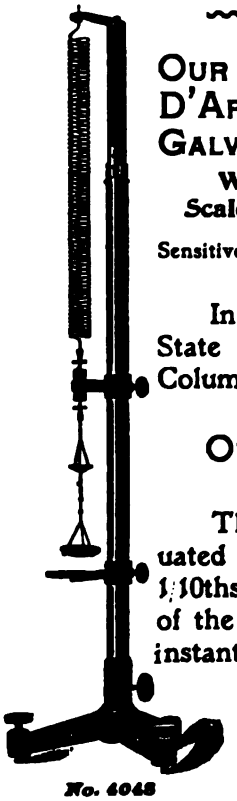

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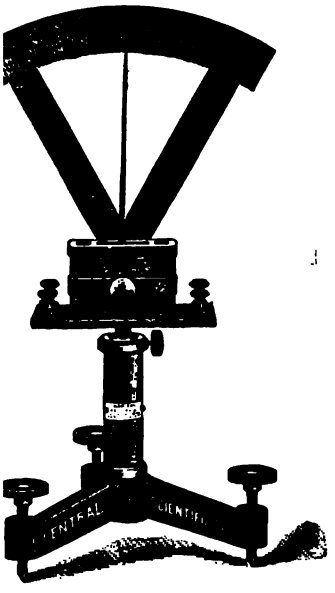

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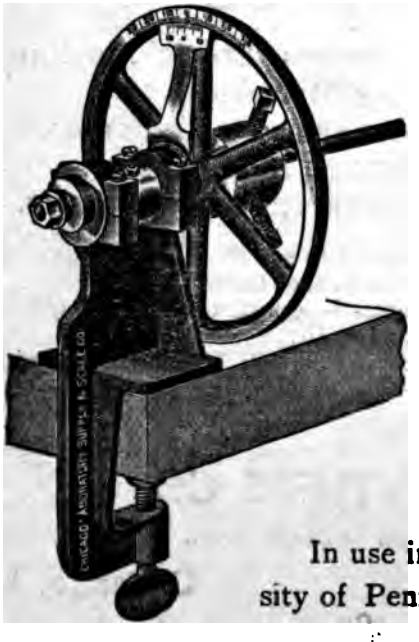

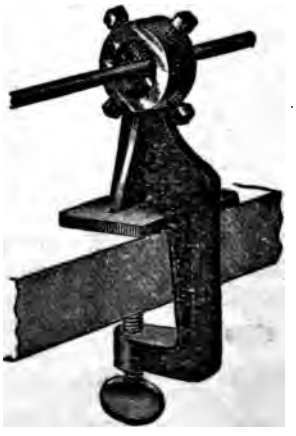

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